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Analog-to-Digital Data Reduction System

J.E. REEGAN

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AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
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PROJECT 4610
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Abstract

Described herein is a new method of recording and processing large amounts of propagation and signal strength data on perforated tape by means of an automatic analog-to-digital conversion and time recording system, with data reduction and curve plots performed by a biquinary computer.

A digital voltmeter and digital clock sample the input data, identify the data as a function of time, and store it digitally. For propagation tests, the analog input is sampled at a one-second rate. The information stored in the converter is read out in a biquinary digital code on punched tape. This tape is then processed by a biquinary computer. Specific numerical values for each one-second sample can be presented on a flexowriter. The computer automatically determines the mean values, computed at one-minute intervals and feeds these mean values through an X - Y variplotter associated with the computer where a distribution curve is automatically plotted. This data reduction system, although of special value in radio propagation research, may also be used wherever amplitude is plotted vs. time.

Acknowledgments

The author wishes to thank C. J. Hartman of the Computer and Mathematical Sciences Laboratory who performed the computer programming, reducing, and plotting of the digital data; F. H. Cook of the same laboratory for his recommendations regarding the tape format; and R. A. Bradbury of the Communication Sciences Laboratory for his helpful suggestions in the development of the circuitry for the readout gates.

Table of Contents

List of Illustrations

ANALOG-TO-DIGITAL DATA REDUCTION SYSTEM

1. Introduction

STATEMENT OF GENERAL PROBLEM

For the past four years experiments conducted in the ionospheric scatter mode of VHF radio wave propagation by the Air Force Cambridge Research Laboratories have resulted in a tremendous amount of propagation data for analysis. One test alone could produce over twenty thousand bits of information. This involved the manual scaling of charts and the laborious reduction of subsequent data thus obtained by a tedious and time-consuming pencil and paper process.

During periods when numerous tests were performed (9 flights in May 1961) it was impossible to keep abreast of the data. This is important because an analysis of one test may disclose areas in which subsequent tests can be improved. Furthermore, the repetitious nature of manual scaling and pencil data reduction eventually becomes monotonous to the extent of causing human errors and slowing down the output as the input of data increases. Therefore, in order to improve data taking and speed up analysis procedures there is a need for computer processing that will give us a combination of accuracy, reliability, and speed.

STATEMENT OF SPECIFIC PROBLEM AND GOALS

To manually scale a minute of recorded data on an Esterline-Angus recorder one lays a calibrated scale across the chart and determines the highest and lowest levels of the signal within that period. He then estimates the middle or intermediate between these levels and calls it the median. "Eyeballing" of this kind can vary from one hour to the next, or from one person to another, and can be especially inaccurate in the case of rapidly varying amplitudes.

A median number has been defined as the middle number in a series containing an odd number of items, for example, 7 in the series 1, 4, 7, 16, 43 and the number midway between the two middle numbers in a series containing an even number of items, for example, 10 in the series 3, 4, 8, 12, 46, 72. To require an eye to extract an elusive median number from a signal almost buried in noise, especially when the width of the ink line itself is approximately 0.5 db, seems to be asking too much in the way of accuracy.

The specific problem then, was how to replace the eye with a computer and how to extract enough information from the minute of data to enable the computer to select the exact median number. Factors involved were the type of computer to be used and the method of converting the signal amplitude into a suitable code for entry into this computer, with a built-in format to guide the computer in its operations. It seemed that 59

one-second samples should provide adequate information and provide the odd number required for a median selection, leaving the 60th sample as a time mark to identify each median. For this an electronic clock was necessary.

Since AFCRL maintains a Remington-Rand solid-state biquinary computer, a digital tape output was most advantageous. The perforated tape has many advantages over ink recordings:

a) It can be used in association with computers and other data processors.

b) It can be transmitted by radioteletype or by landline teletype to be processed by computers. Any selected perforating code can be produced, permitting the recorded data to be fed directly into a computer or to be transmitted over long distances using standard teletype equipment without loss of accuracy. This allows a central data-reduction station to serve any number of data-gathering installations.

c) The resulting tape produced by the computer can be applied to an X-Y Variplotter to automatically plot a desired distribution curve.

d) It can be converted by the computer itself into a card-punch code for use on an IBM 650 computer.

e) It can drive flexowriters or electric typewriters.

2. Discussion

SYSTEM AS A WHOLE

With these guidelines a system was devised as shown in Figure 1.

A digital voltmeter (Appendix A) was used to register the analog signal input, thus assuring that many varieties of tests could be performed with this system because any input capable of operating the voltmeter could be used as data. Since we were engaged in field-strength measurements our source of information would come from the AGC outputs of sensitive receivers.

A ten-line decimal code output type was chosen rather than the analog output type because the potential drops across the nixie display lights made excellent on-off states for storing in the converter.

The increase in accuracy when the digital voltmeter was used instead of an ink recorder became immediately apparent. For example, after calibrating the voltmeter in dbm's it was found that 127 dbm registered at 743 and 128 dbm at 707. This gave a spread of 36 numbers over a 1-db range. Then if the selected median is 730 it becomes 127.361 dbm when converted by the computer. The eye, looking at that level on an ink recorder, would interpret it as either 127 or 128 dbm. The flexibility of the computer plotting board, on the other hand, ranging in size from nine square feet to the size of a postage stamp, allows for a greater degree of detail.

A digital clock was designed and constructed locally (Appendix A.2) to provide outputs similar to those of the voltmeter with the same type of storage. The sampling rate was set at 59 ppm with the 60th pulse for recording time on the tape.

All the information was printed on a tape punch (Appendix A.3).

A flexowriter (Appendix A.4) was provided as an off-line device for spot-checking, if necessary, before the information was fed into the computer.

The most serious problem encountered was that of designing a converter that would read out whatever was stored in its input gates and transform it into a biquinary coded output. Figure 2 shows a block diagram of the final design.

THEORY OF CONVERTER OPERATION

Assuming that the digital voltmeter and digital clock are registered at the inputs as OFF – ON states whose levels are +115 and +15 vdc respectively, the following operations take place.

Decade Gates and Readouts

Figure 3 shows a typical decade gate. With all readouts enabled the switching point from the OFF to the ON state is +55 vdc, which is conveniently close to the midpoint of both states.

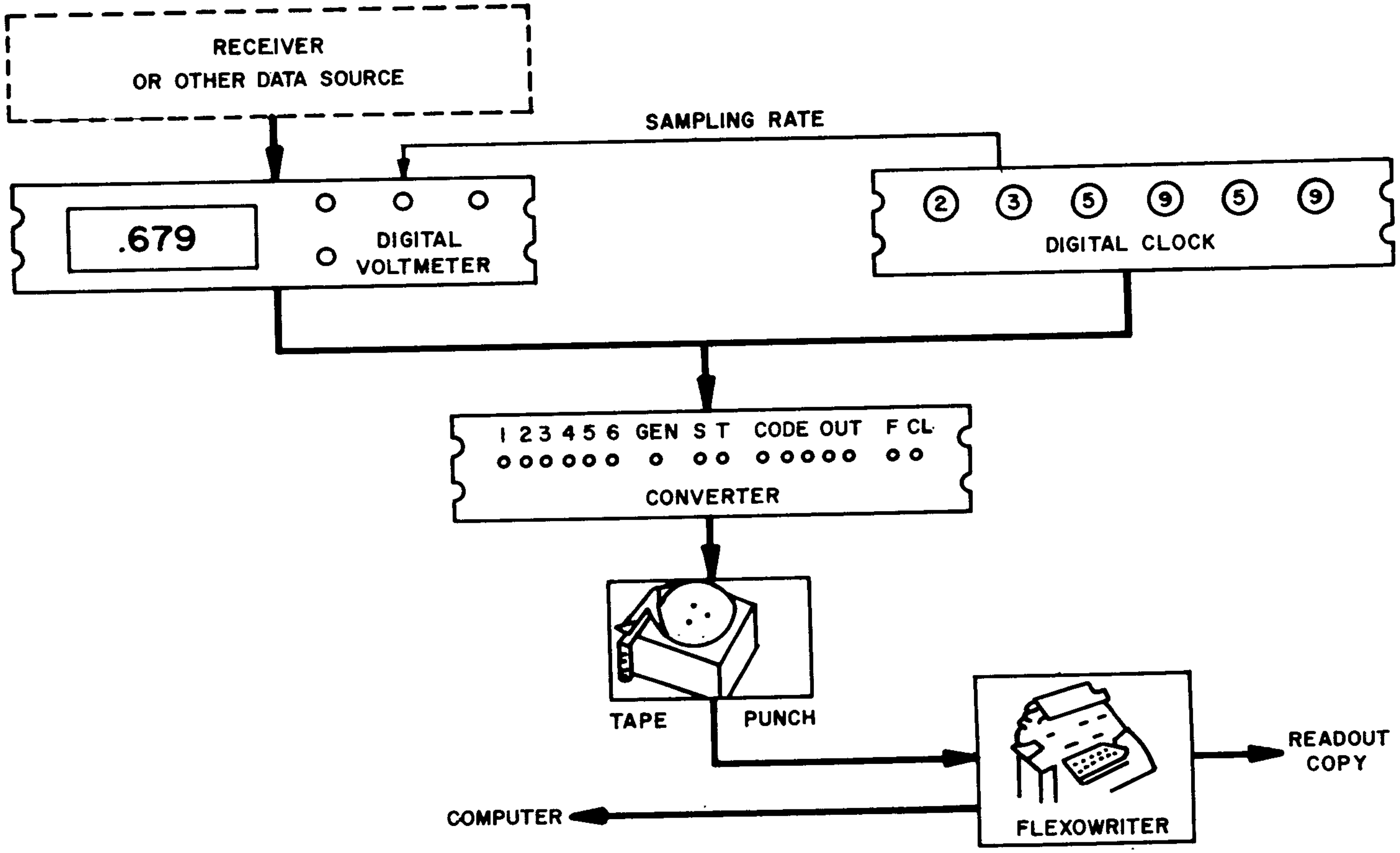


Figure 1. Analog-to-Digital Data Reduction System

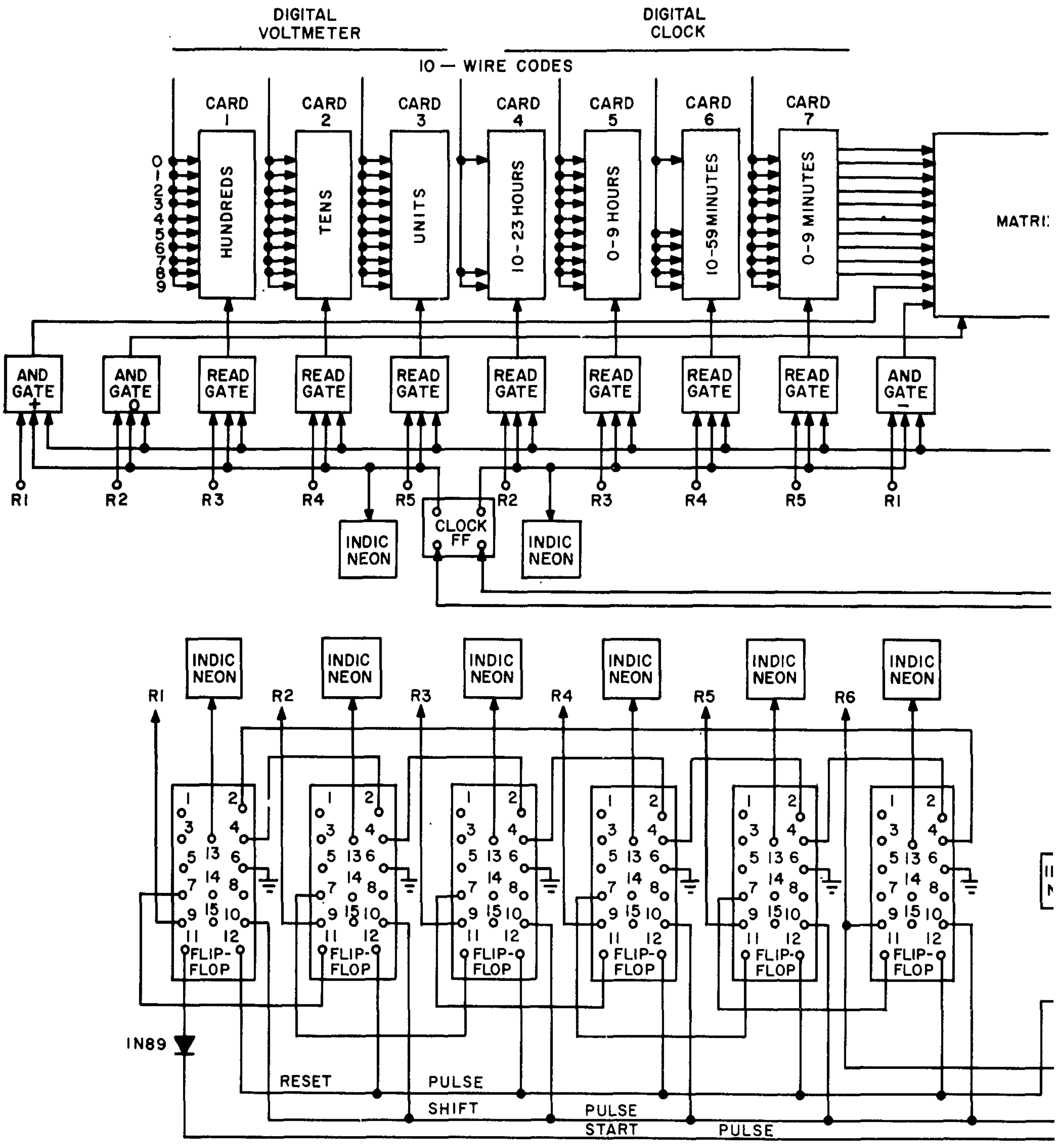
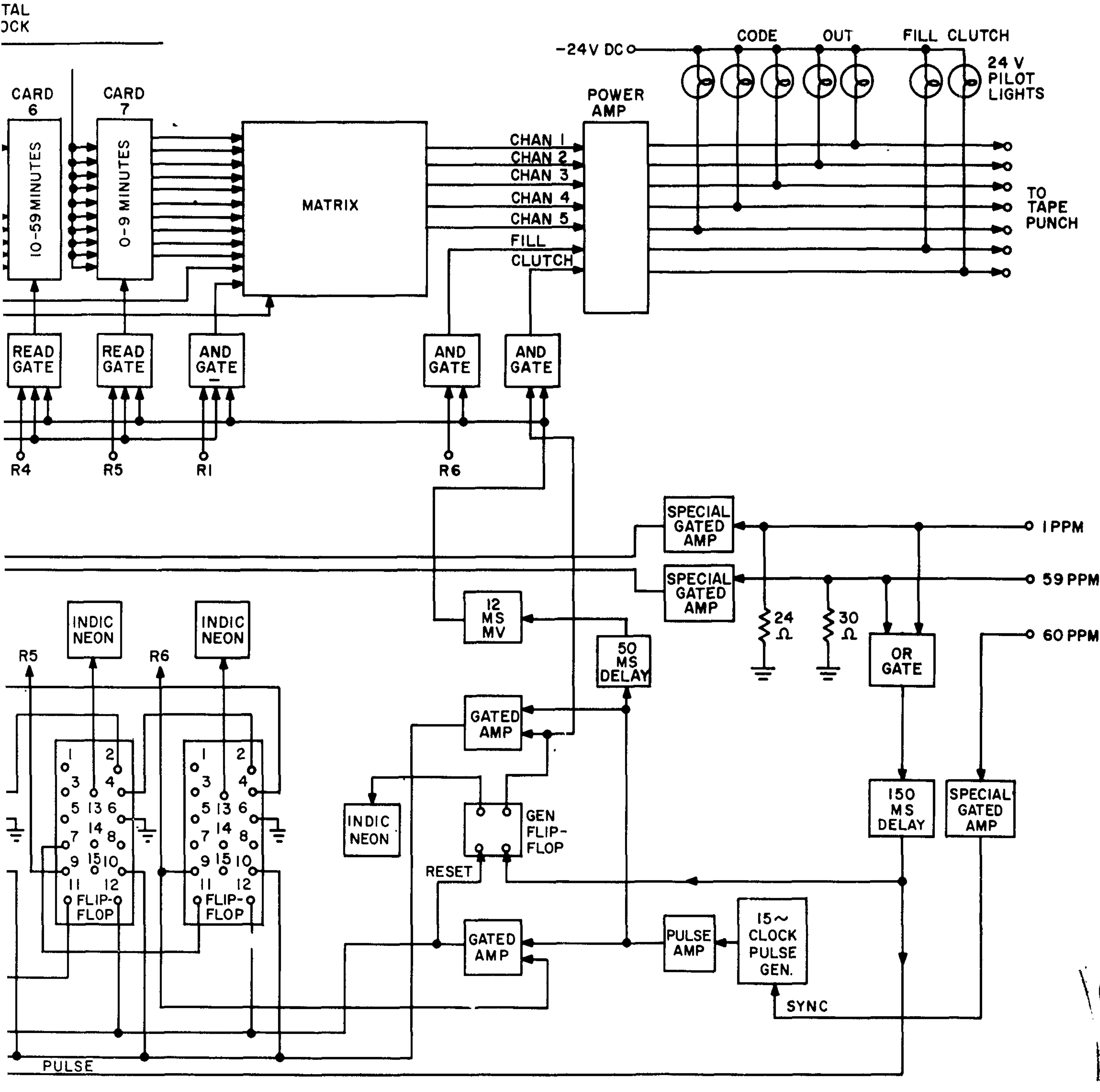


Figure 2. Analog-to-Digital Converter Block Diagram



2. Analog-to-Digital Converter
Block Diagram

2

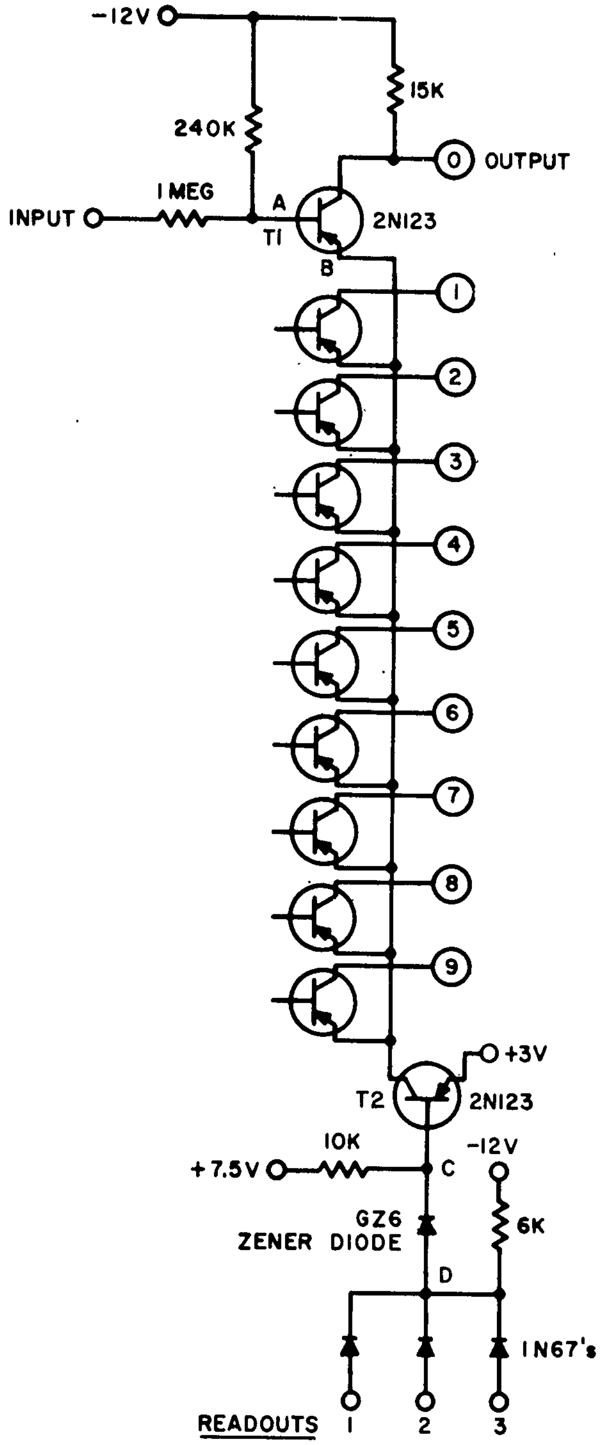


Figure 3. Decade Gate T_1 with Readout Gate T_2

Point A is controlled by the OFF-ON states. In the ON state the voltage at this point is at the emitter bias of +3v and the collector conducts. In the OFF state it is driven more positive to +6v and transistor T_1 cuts off.

Point B is set at +3 vdc and is controlled by the readout gate. Whenever a readout input is disabled point B drops to zero and transistor T_2 cuts off. Transistor T_1 therefore does not conduct and any switch to the ON state only drives point B more negative.

Point D is controlled by the zero to -6 vdc flip-flop levels coming into the readout inputs. With all readouts enabled it is at -6 vdc and the zener diode maintains point C at + 3 vdc. When any of the three readouts is disabled (drops to zero) point D also drops to zero and point C goes more positive to +6 vdc thereby cutting off T_2.

The readout is a 3-input AND gate. Input 1 is enabled by the flip-flop counters; input 2 is enabled by the samples/time flip-flop; input 3 is enabled by the 15-msec multivibrator. To operate the AND gate all inputs must simultaneously be at -6 vdc level and when this occurs all ten gates in the decade controlled by this gate will read out whatever OFF-ON state is present at their inputs. Only one ON state, of course, will be present at any one time.

AND Gate

The AND gate is the same as the decade and readout gate described above except that the OFF-ON input is grounded. By grounding this input the circuit is always in a conducting state and may be controlled directly from the readout inputs as shown.

Format

Six counts are used to accomplish the following format:

TIME - X X X X (FILL)
SAMPLE + X X X X (FILL)

The minus sign orders the computer to search for a median between it and the preceding minus sign.

The plus sign orders the computer to store each sample until a median is needed. The fill sign represents a carriage return only for the flexowriter.

Readout Counter

Flip-flops are used in a shift register and counter combination, as in Figure 4, to read out in correct order the program format and the information stored in each decade column. The initial start pulse sets the first stage and gates on a local 15-cps pulse generator which supplies seven shift pulses, the last pulse serving to reset all stages for the next sample.

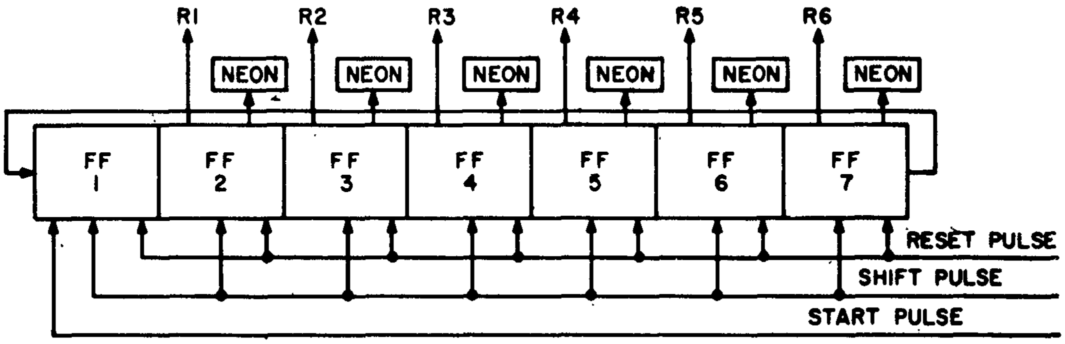


Figure 4. Readout Counter Block Diagram

Neon Indicating Circuit

The indicating circuit shown in Figure 5 operates directly from one collector output of the flip-flop controlling it. The conducting side of the flip-flop turns on the indicator while the nonconducting side furnishes the -6v level for operating the decade readout gate.

Clock Flip-Flop

A method was needed for switching from samples to time and back again. Since each flip-flop has a count input and a reset input it was convenient to use the reset input for the 59 1-sec pulses, thus holding the flip-flop in a continuous state. The count input is used for the 60th second, or one-minute pulse, thus switching the circuit from samples to time. On the following 59 pulses it again resets on samples readout and the cycle is repeated. Neon indicators previously described are provided to show that it is operating properly.

Local Pulse Generator

A characteristic of the Sylvania flip-flops used in this system is that if no count input is physically present (no wire connected) the circuit becomes a free-running multivibrator operating at a 250 kcps rate. By inserting additional capacitors on either side the rate may be slowed to a 15-cps square wave generator which, with the addition of a differentiator and pulse amplifier, comprises a 2-module local pulse generator synchronized by a 1-sec output pulse from the digital clock.

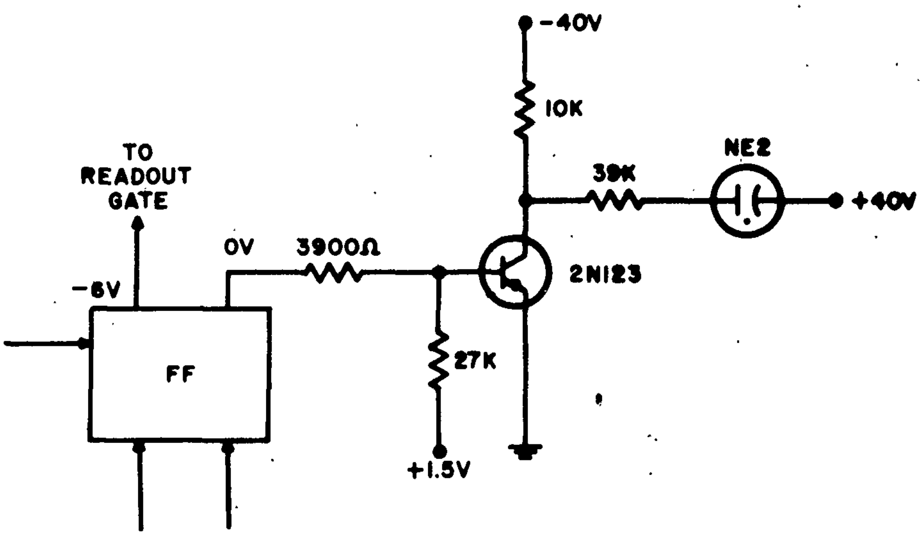


Figure 5. Neon Indicator Circuit

Generator Flip-Flop and Gating Circuits

The generator flip-flop is switched by either the 1-sec or the 1-min pulse from the digital clock. This (1) enables the AND gate controlling the tape clutch magnet and (2) enables a gated pulse amplifier which permits a chain of shift pulses to pass from the 15-cps pulse generator. When the last pulse is shifted out of the counter it in turn enables another gated amplifier in parallel with the first which resets both the generator flip-flop and the counter, thus cutting off the chain of pulses and restoring all flip-flops to their original states. Figure 6 shows a block diagram of these circuits.

15-MS Multivibrator

In order to operate a motorized tape punch, the control impulse for the clutch and code magnets should have a minimum duration of 15-msec. A one-shot multivibrator is used to lengthen the pulse for the period required to punch each code unit on the tape. The circuit is shown in Figure 7.

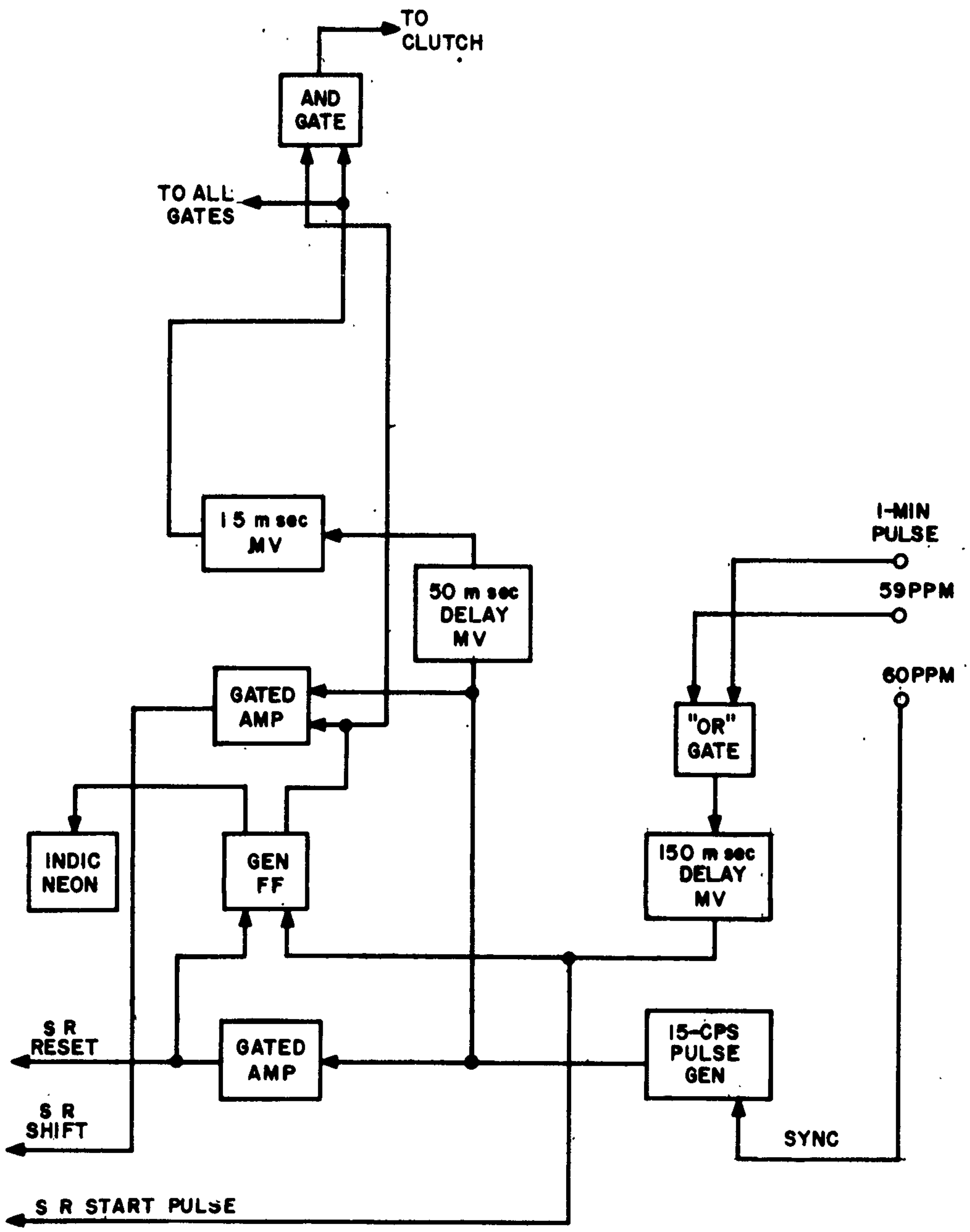


Figure 6. Generator and Timing Gates Block Diagram

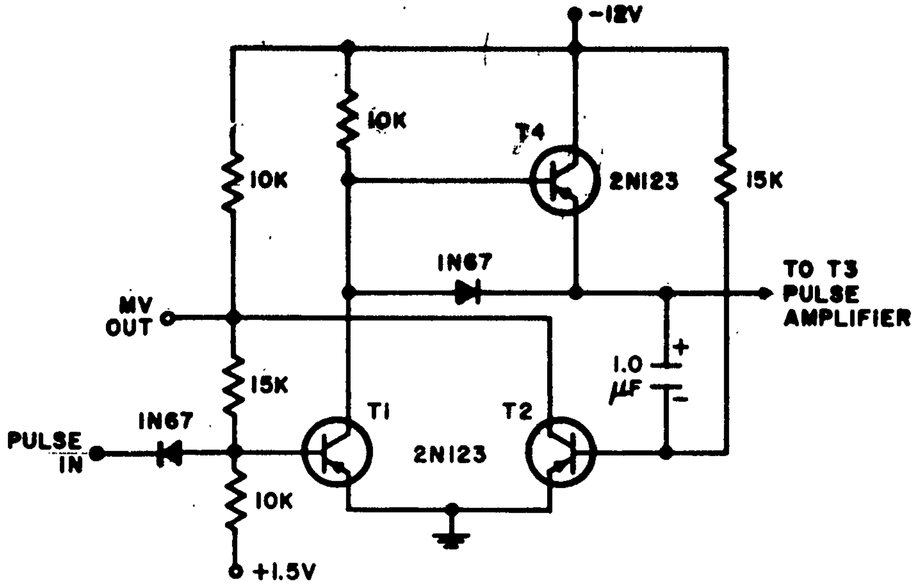


Figure 7. 15 Millisecond Multivibrator

Matrix

A biquinary matrix is used to produce the following code:

	Channel		
No.	76	5	4321
1	00	0	0001
2	00	0	0010
3	00	1	0011
4	00	0	0100
5	00	0	1000
6	00	1	1001
7	00	1	1010
8	00	0	1011
9	00	1	1100
+ and 0	00	1	0000
-	00	1	0101
fill/tab	10	0	0000

Other codes may be used depending on the computer to be employed. The matrix directs the binary-coded decimal into the proper punch magnets in accordance with the wiring of the flexowriter associated with the computer.

Power Amplifiers

In order to operate code punch magnets drawing relatively heavy currents the signal must be amplified. This is accomplished by a 2N43 driving a 2N301A transistor power amplifier for each channel output. A separate -24-vdc power supply energizes the code magnets in series with the collectors.

Output Code

The output of the converter is shown by 28v 20-ma pilot lamps connected across each channel. They are displayed when current flows in the collector circuit of the 2N301A transistors.

The converter with its various components is shown in Figures A.5a and A.5b.

The assembled data reduction system is housed in a 4-ft rack as shown in Figure A.6. The flexowriter, Figure A.4, is used off-line as a visual check of data before it goes into the computer.

3. Results

The new system was used at the Air Force's Oak Hill receiving site in Littleton, Mass. during the KC-135 ionospheric scatter propagation tests conducted in May 1961. During this month nine flights were made. Data was simultaneously recorded on an Esterline-Angus ink recorder and on an analog-to-digital converted tape.

Table 1 shows a sample of raw data recorded on the digital meter and Table 2 the manner in which the computer arranged the data and selected the minute median. This procedure was followed for every minute of recording as shown in the 10-min sample of Table 3, which also compares the computer answers with the visual answers. Both methods follow the same general pattern but the machine method allows for greater accuracies because the hand method is only an approximate solution.

Table 1. 59 samples of raw data from digital meter 18 May 1961
Time 12:24 A. M.

	-0023		+0357
1 ---	+0388		+0276
	+0292		+0484
	+0268		+0263
	+0254		+0298
	+0811		+0282
	+0203		+0229
	+0625		+0913
	+0433		+0389
	+0236		+0262
	+0269		+0371
	+0183		+0210
	+0204		+0241
	+0418		+0238
	+0229		+0175
	+0225		+0197
	+0250		+0192
	+0366		+0497
	+0337		+0558
	+0346		+0778
	+0259		+0472
	+0363		+0581
	+0279		+0497
	+0224		+0268
	+0291		+0339
	+0300		+0370
	+0295		+0435
	+0253		+0199
	+0377	59 ---	+0288
	+0270		-0024
	+0368		

Table 2. 59 samples arranged in numerical order and median selected by computer.

1 ---	913	288
	811	282
	778	279
	625	276
	581	270
	558	269
	497	268
	497	268
	484	263
	472	262
	435	259
	433	254
	418	253
	389	250
	388	241
	377	238
	371	236
	370	229
	368	229
	366	225
	363	224
	357	210
	346	204
	339	203
	337	199
	300	197
	298	192
	295	183
	292	59 - 175
30 ---	291	--- 132.256 dbm

Table 3. Comparison of machine vs. hand data reduction.

COMPUTER REDUCED DATA			HAND REDUCED DATA
Time	Dig. Meter median	dbm	dbm
0019	0429	128.390	128
0020	0232	134.672	137
0021	0348	130.520	130
0022	0383	129.598	130
0023	0302	131.896	132
0024	0291	132.256	130
0025	0202	136.045	137
0026	0619	123.650	123
0027	0449	127.850	127
0028	0374	129.832	132
0029	0339	130.754	130
0030	0166	138.400	137

18 May 1961

Note that only whole numbers can be determined.

The time required for the computer to select the minute median levels for an entire flight was 20 minutes.

This tape was then read into an X-Y Variplotter associated with the computer and a distribution curve was plotted. The time required to plot this curve was an additional five minutes. After cutting a tape on the circuit under test, the entire time to reduce the data and plot the curve of a flight on a programmed computer was 25 minutes. The time required to reduce the data and plot curves for nine flights was 3 hours and 45 minutes.

Using the manual method, the E. A. ink recordings were scaled by a mathematician who, with a comptometer, stored the data on paper and plotted the curves by hand. The time required to process one flight was one day. As the flights continued, the process became tedious and the time increased to one and one-half, and finally to two days. The time required to process the nine flights was 15 days.

For comparison purposes three curves are shown for the flights of 3 May, 10 May, and 17 May. In processing by computer, the entire flight is plotted as one curve whereas the manual method divides it into two parts, outbound and inbound. Plotting as one curve has distinct advantages in that it shows the test as a whole and permits an immediate evaluation of propagation changes occurring between the beginning and the ending of the test, the effect of daylight and darkness, the variation of noise levels, or the difference between the tail and the nose antennas of the aircraft.

Figures 8a and 8b show the outbound and inbound hand curves for 3 May. The areas outlined are the ionospheric regions where digital recordings were taken and plotted by the computer with the resultant curve shown in Figure 9 for the same flight. This shows a greater scale expansion and a wider distribution of signal levels made possible by the instantaneous response of the digital meter at the precise moment of sampling. To obtain such a distribution manually would require a fast recorder such as the Sanborn Recorder, and the task of visually scaling such a chart would be immeasurably increased.

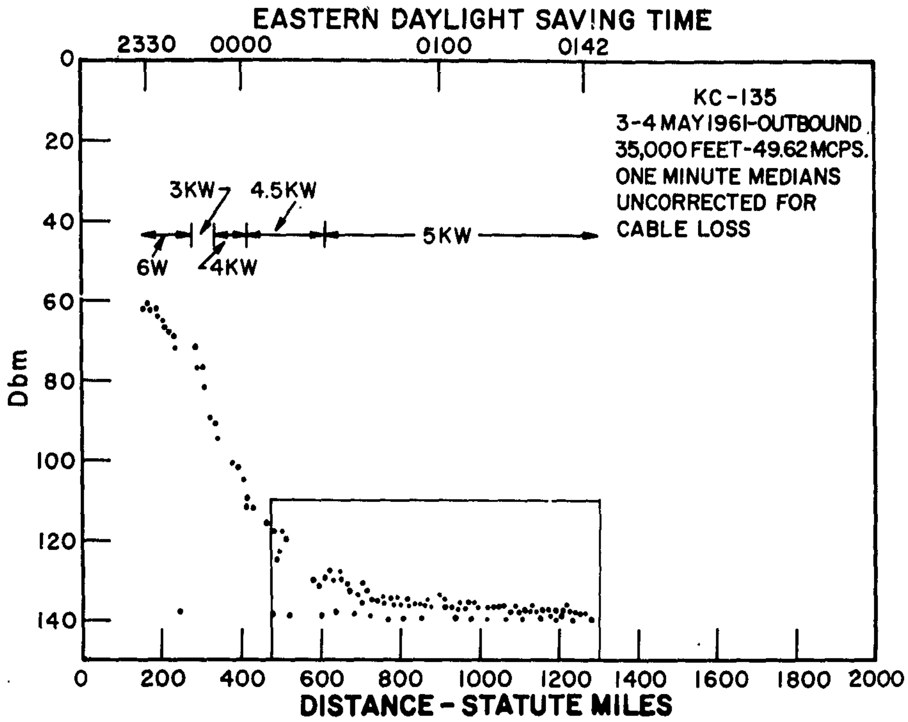


Figure 8a. Hand Curve – Outbound 3 May

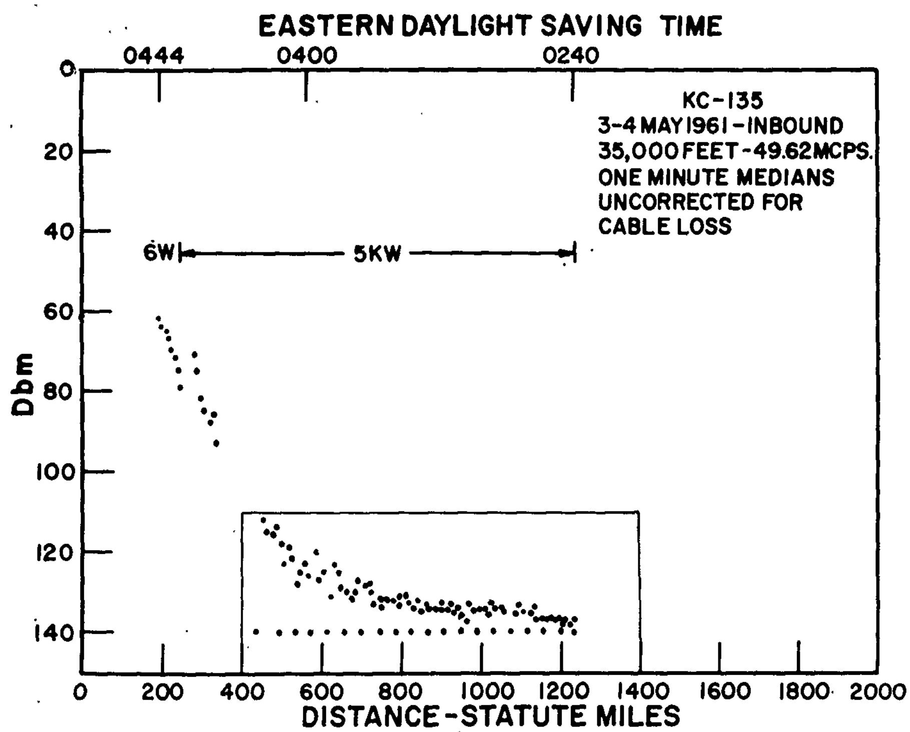


Figure 8b. Hand Curve – Inbound 3 May

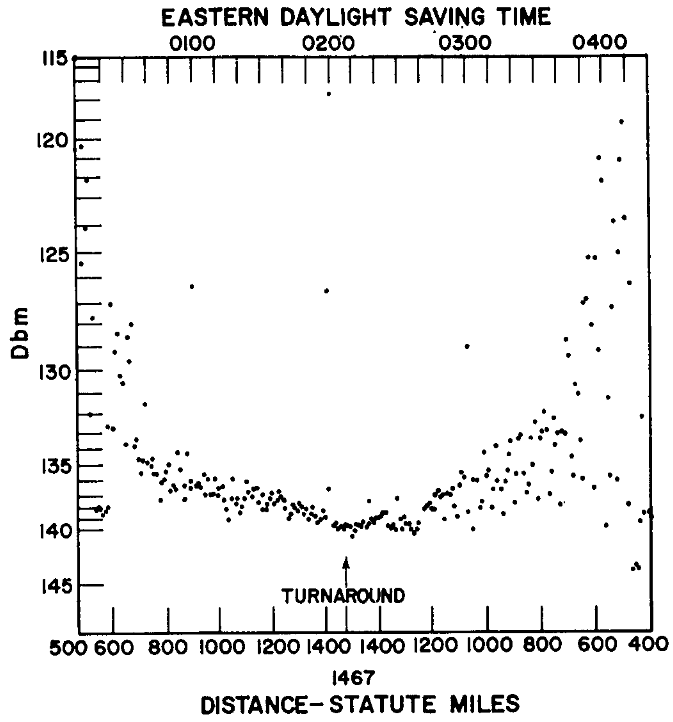


Figure 9. Machine Curve – 3 May

Figures 10a, 10b, and 11 show similar comparisons for 10 May, and Figures 12a, 12b, and 13 for 17 May.

Note that in Figure 11 (10 May) the noise level is between 137 and 140 dbm as contrasted to a steady 140 dbm on the manual chart. This is caused by a lack of synchronization between the plane transmitter and the ground receivers. This was a corollary test on a noninterference basis with standard tests underway where the plane transmitted to the ground with a carrier four minutes on and one minute off for a noise level check. Because a visual chart indicates the presence or absence of a signal, it is not necessary to accurately synchronize the air and ground. As a result delays of as much as ten seconds could occur in manually turning on and off the transmitter. The computer, however, is controlled by the precise 60th second of each minute and it sees and acts upon both signal and noise if both are present. Therefore, unless automatic synchronization is provided, the noise intervals recorded by the computer will read slightly higher because some samples of the carrier will get in.

During the last flight of the May series an enhancement of the signal occurred during the entire test due to an unusual aurora display. This resulted in the signal exceeding the digital meter limit of .999 and being treated by the computer as a low number. This problem was solved by adding another digit to the meter and disabling the decimal point to permit tropo-scatter and signal enhancements to be recorded.

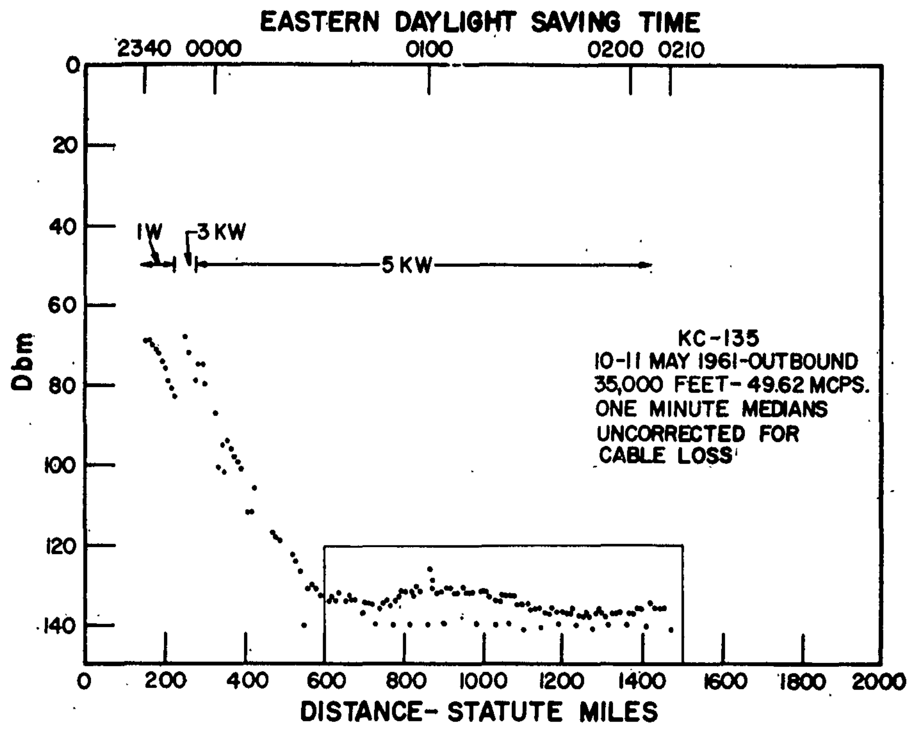


Figure 10a. Hand Curve – Outbound 10 May

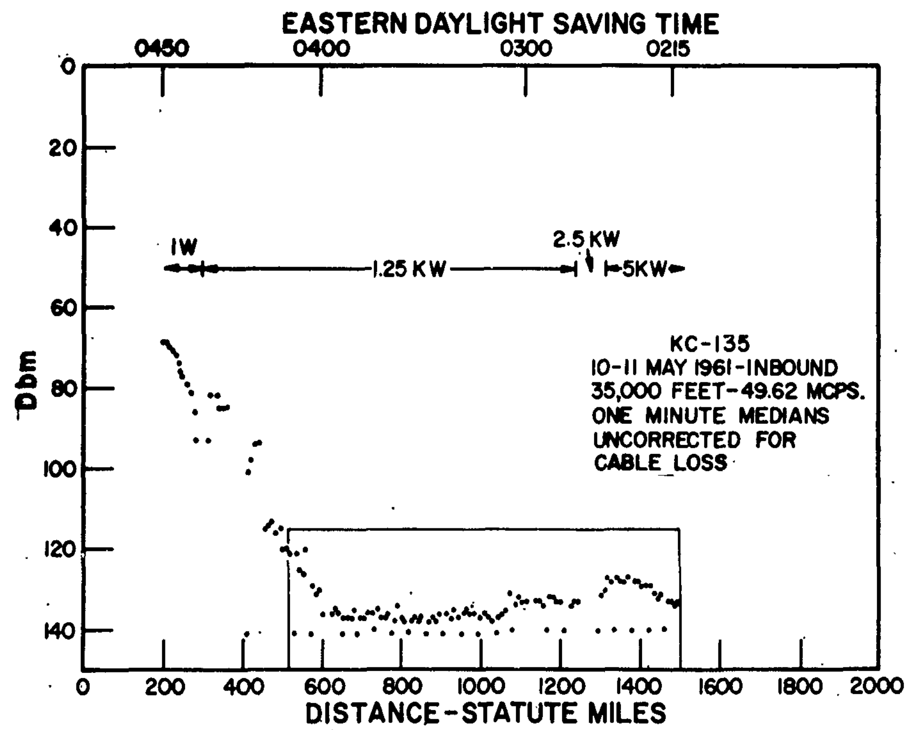


Figure 10b. Hand Curve – Inbound 10 May

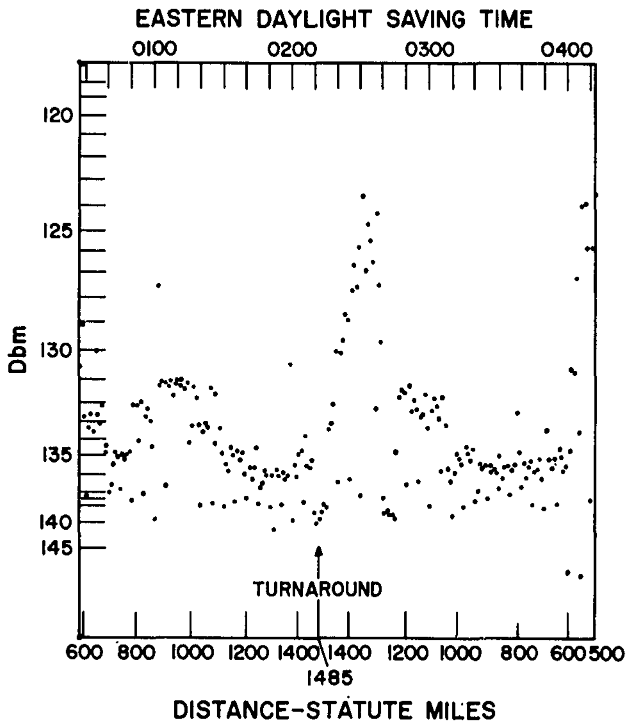


Figure 11. Machine Curve — 10 May

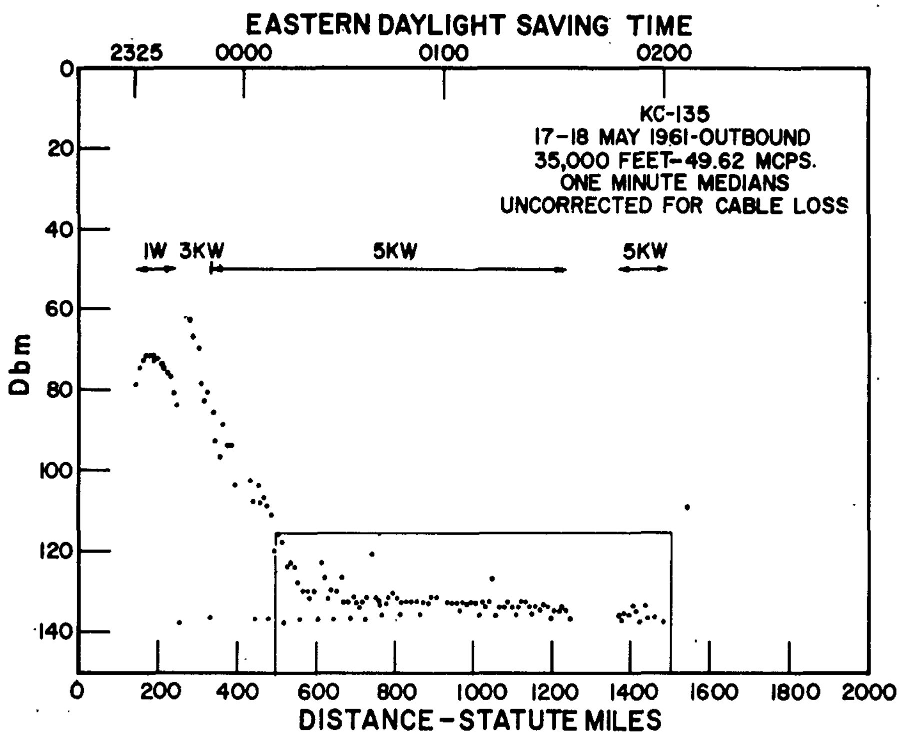


Figure 12a. Hand Curve — Outbound 17 May

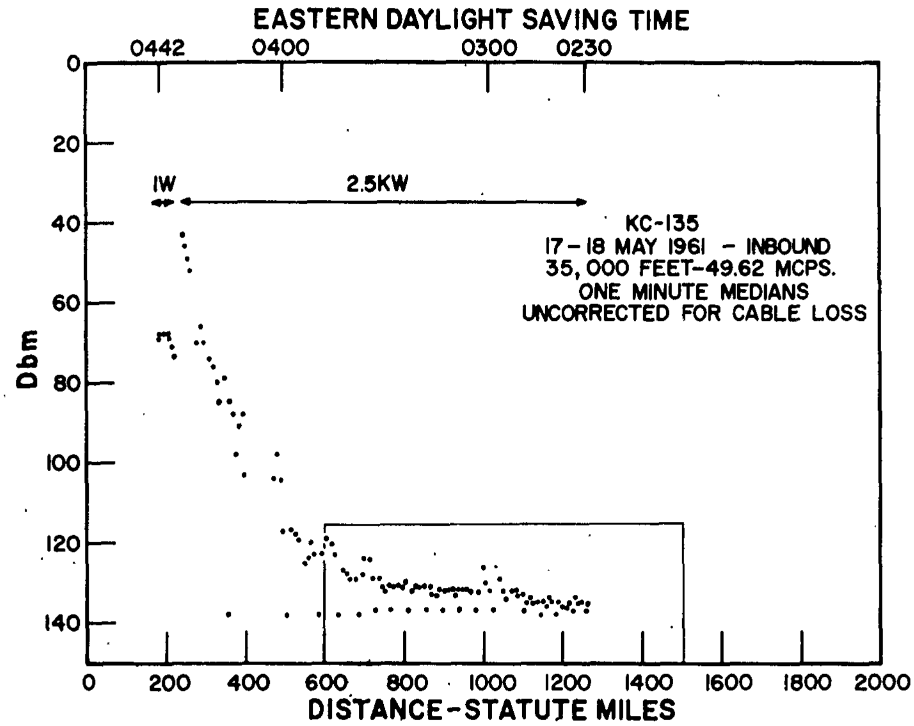


Figure 12b. Hand Curve – Inbound 17 May

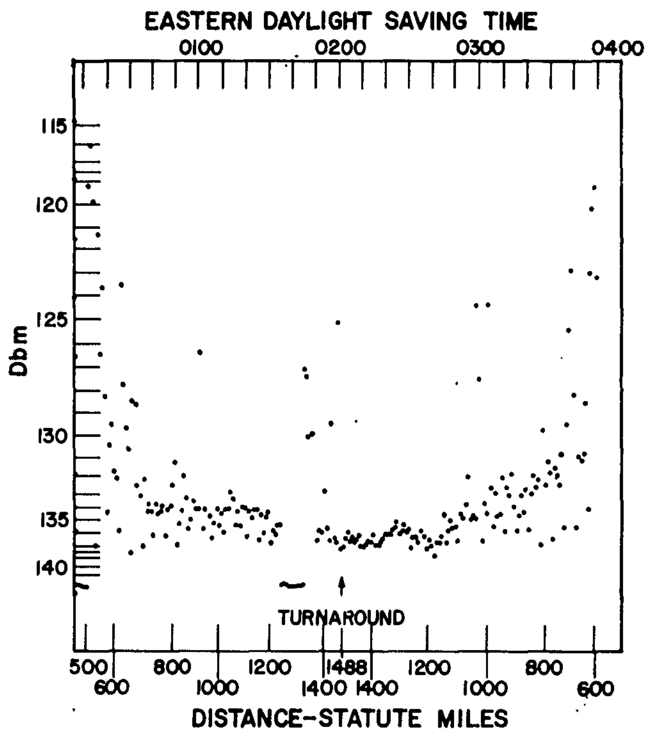


Figure 13. Machine Curve 17 May

4. Conclusions

The system described is geared to the technological advances of the state-of-the-art in electronic technical development. It is an extension of investigative findings of a scientific and technical nature into practical application. It is a technique for which it is anticipated there will be an increasing requirement. The activity began with actual development and was directed towards the establishment of a specific technical capability. Anticipated needs are self-evident.

The entire system, including the computer, is a solid-state device. It can record and process data faster and do the job better. It can perform in 25 minutes what it now takes us 8 hours to do. It can record data with greater accuracy than manual methods. Its components are smaller, require less power, and are more reliable than vacuum tubes. It therefore meets all the requirements of accuracy, reliability, and speed.

This concept of digital data reduction has great potential value for the research program in many areas of radiowave propagation, meteor hits, satellite or millimeter-wave communications, data transmission, amplitude modulation, and laboratory measurements.

Appendix A

Included in Appendix A is a description of each of the components of the Digital Data Reduction System.

DIGITAL VOLTMETER (Figure A. 1)

A Hewlett-Packard 405AR digital voltmeter gives nixie-light displays and 10-line decimal code outputs. When the nixie light of any decade counter is dark the output potential is +115 vdc. When it is displayed the output potential drops to +15 vdc. These two potentials are used as off-on states to set up corresponding decade-gate circuits in the converter. The sampling rate is externally controlled by the sampling rate of a digital clock which also acts as a hold-off signal to prevent any operation during intervals between readings.

DIGITAL CLOCK (Figure A. 2)

The digital clock, constructed at AFCRL, is a mechanical-electrical device using stepping relays and was designed to operate from nixie light displays and 10-line decimal code outputs similar to the digital voltmeter.

It has four pulse outputs in addition to the above:

(a) 59 ppm at -20v for reading out amplitude levels under test.

(b) 1 ppm (60th second pulse) at -20v for recording time.

(c) 60 ppm at -20v for synchronizing the converter clock pulse generator.

(d) 60 ppm at +20v for external control of the digital voltmeter sampling rate.

The clock is driven by a 60-rpm Bodine motor which operates microswitches to energize the stepping relays at the specified times. A control on the front panel makes it possible to slow the sampling rate, if desired, to either 55 or 50 ppm.

Reset buttons are provided to set the clock to any initial starting time.

As no requirement existed for precise timing in the field strength measurements underway, the accuracy is that of the 60-rpm Bodine motor and the commercial AC driving it.

TAPE PUNCH (Figure A. 3)

The Friden motorized tape punch (Figure A3) transforms data from the converter into perforated tape for entry into the flexowriter or the computer.

FLEXOWRITER (Figure A. 4)

The Friden flexowriter is an electric typewriter specially modified to operate from a biquinary coded tape.

A standard flexowriter may be used in systems employing a binary operated computer. The computer being used here, however, must have a biquinary code so it was necessary to design the system with that fact in mind.

ANALOG-TO-DIGITAL CONVERTER (Figure A. 5)

The converter accepts signal levels, registered in the digital voltmeter, and time, registered in the digital clock in accordance with the selected sampling rate, and stores them in its front-end decade gates. An input pulse, synchronized by the digital clock, then gates on a local pulse generator which sweeps across the decade gates successively counting off each decade and reading out in parallel whatever is in them.

Neon counting indicators on the front panel visually show the count as it progresses at a 15-cps rate from one through six counts. On the 6th count the FILL indicator lights, showing the end of a sample and the processing of a carriage return command to the flexowriter. On the 7th count, not shown on the front panel, all the flip-flop circuits are reset and all indicators go out except TIME or SAMPLE. These show only the type of recording being taken and are not associated with the count. It should be observed that on every 60th input pulse these indicators will switch from SAMPLE to TIME for one second duration.

The converter output is displayed by five CODE OUT indicators, each of which represents a tape channel. The least significant digit is on the right. For example, the output number 8 would be displayed as 01011 and would be so punched on the tape. Since the tape punch clutch magnet operates for only 15 msec of each count these indicators are displayed very rapidly. The clutch indicator on the panel lights only when the clutch is energized.

POWER SUPPLY

The power supply consists of four constant voltage and three regulated voltage Transpacs, with a separate supply of -24 vdc for the power amplifiers and tape punch magnets.

+1.5 vdc @ 140 ma - regulated bias
+3.0 vdc @ 2 ma - gating and switching levels - constant voltage
+7.5 vdc @ 2 ma - gating and switching levels - constant voltage
+40.0 vdc @ 1 ma - neon indicators - constant voltage
-40.0 vdc @ 35 ma - neon indicators - constant voltage
-6.0 vdc @ 75 ma - flip-flop counting circuits - regulated
-12.0 vdc @ 150 ma - gates and pulse amplifiers - regulated
-24.0 vdc @ 700 ma - power amplifiers, motorized tape punch and flexowriter - regulated

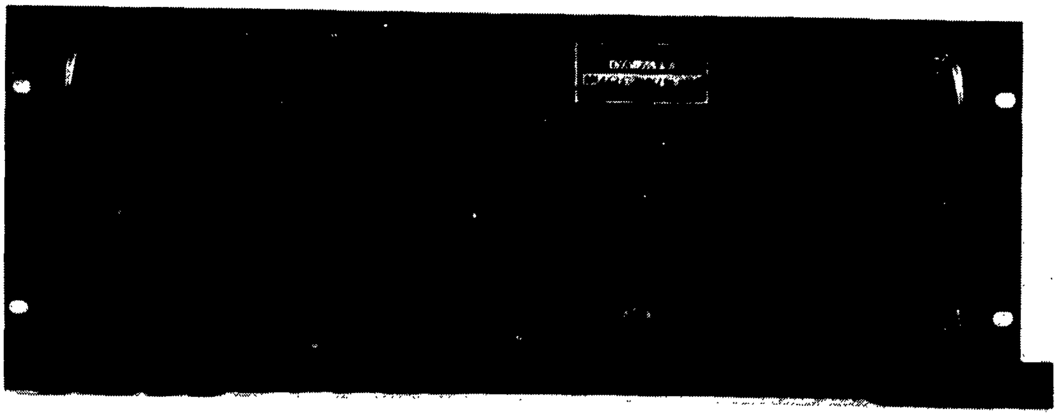


Figure A.1. Automatic DC Digital Voltmeter

Figure A.2. Digital Clock - Front

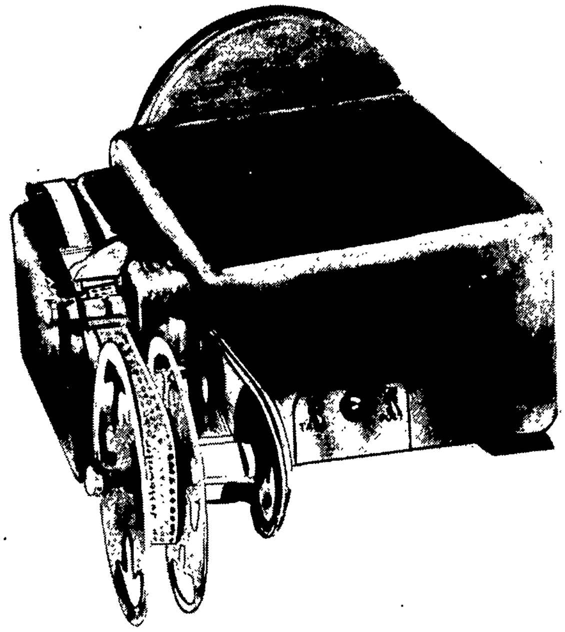


Figure A. 3. Motorized Tape Punch

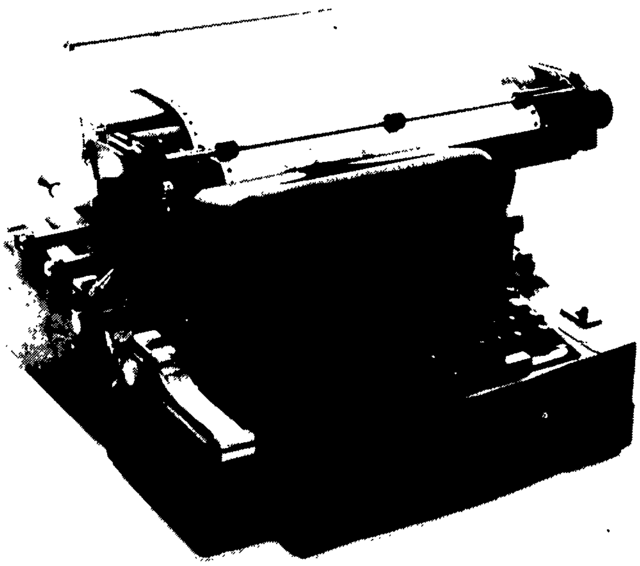


Figure A. 4. Friden Flexowriter

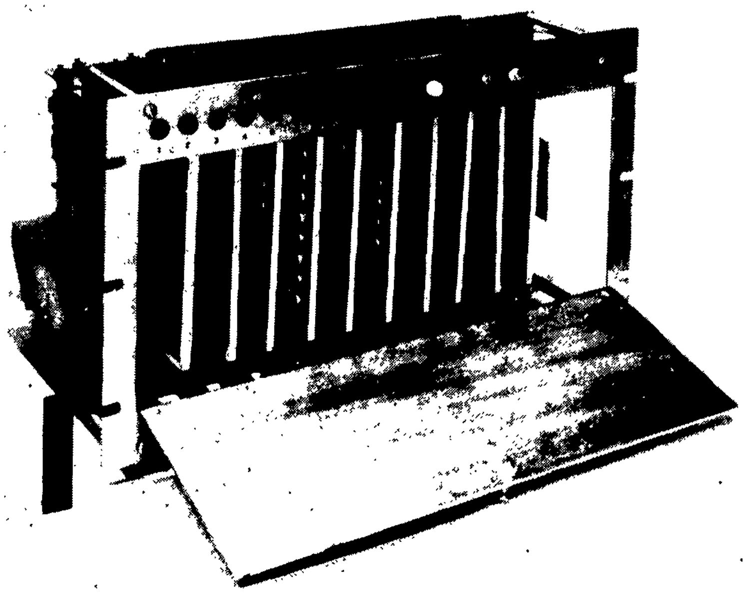


Figure A. 5a. Converter Showing Decade and Gate Plug-In Units

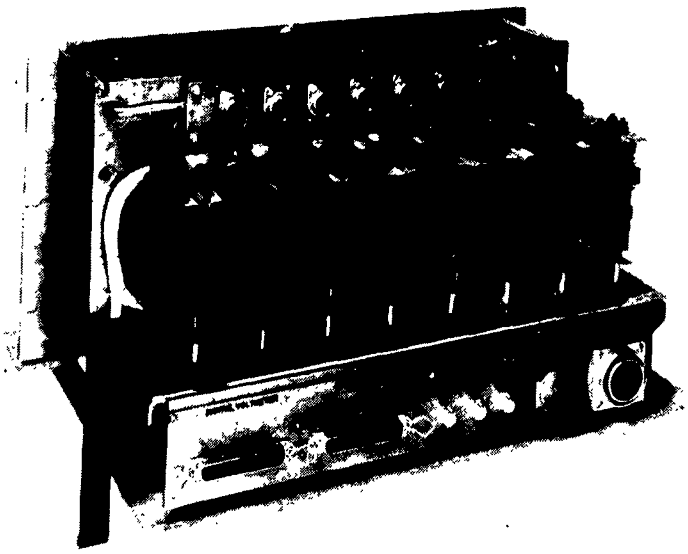


Figure A. 5b. Converter Showing Flip-Flops and Gated Amplifiers

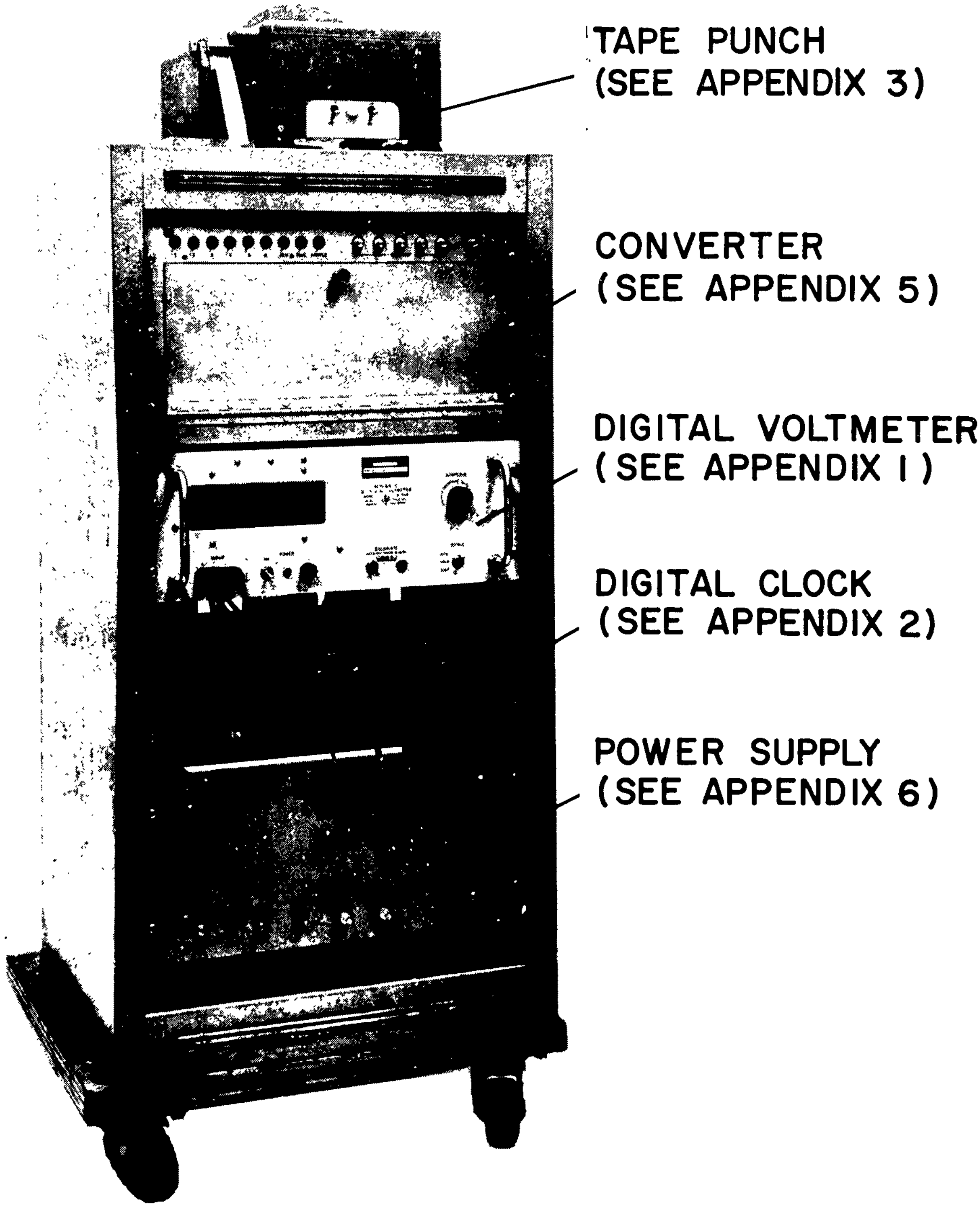
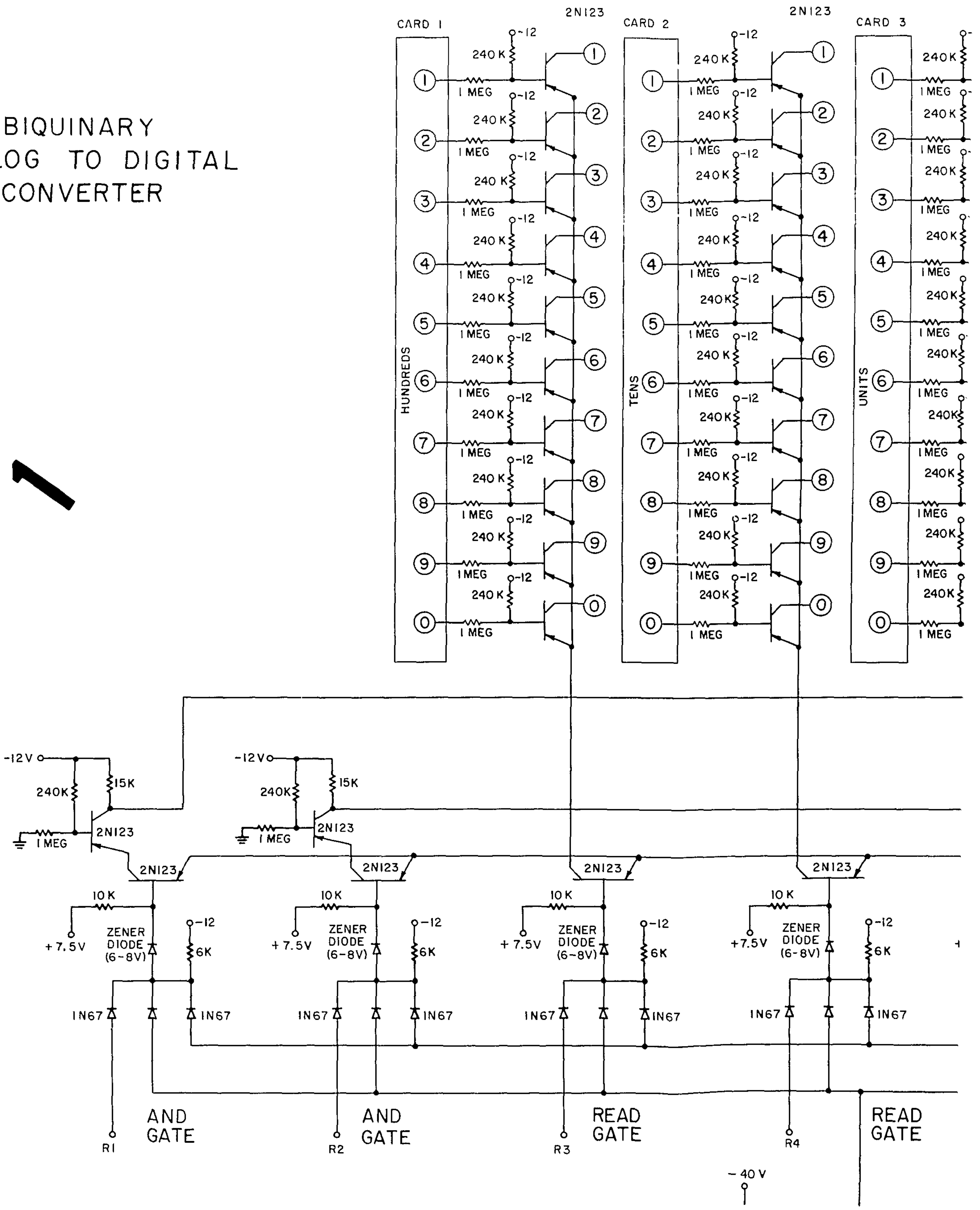


Figure A.6. Digital Data Reduction System

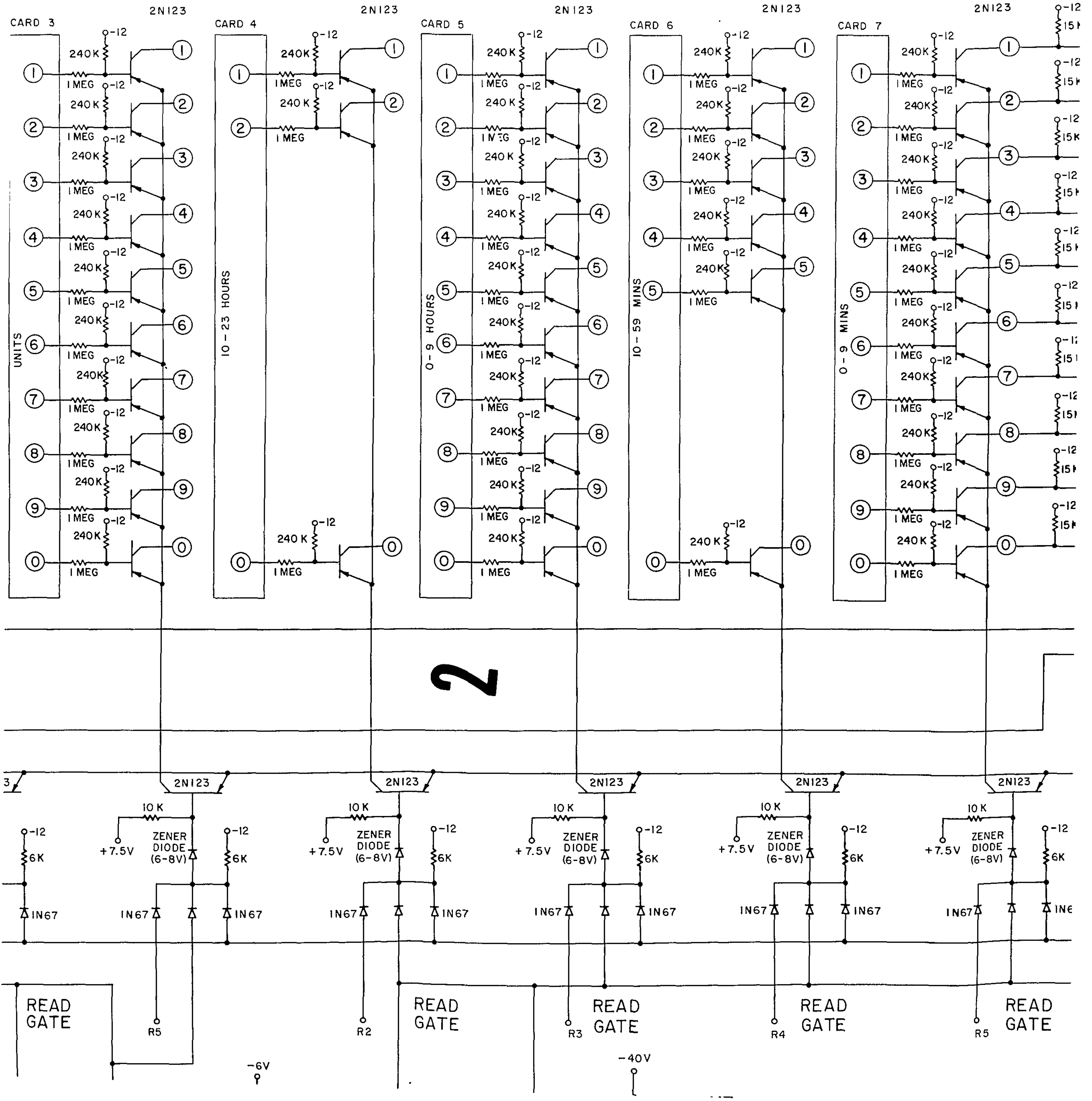
DIGITAL VOLTMETER

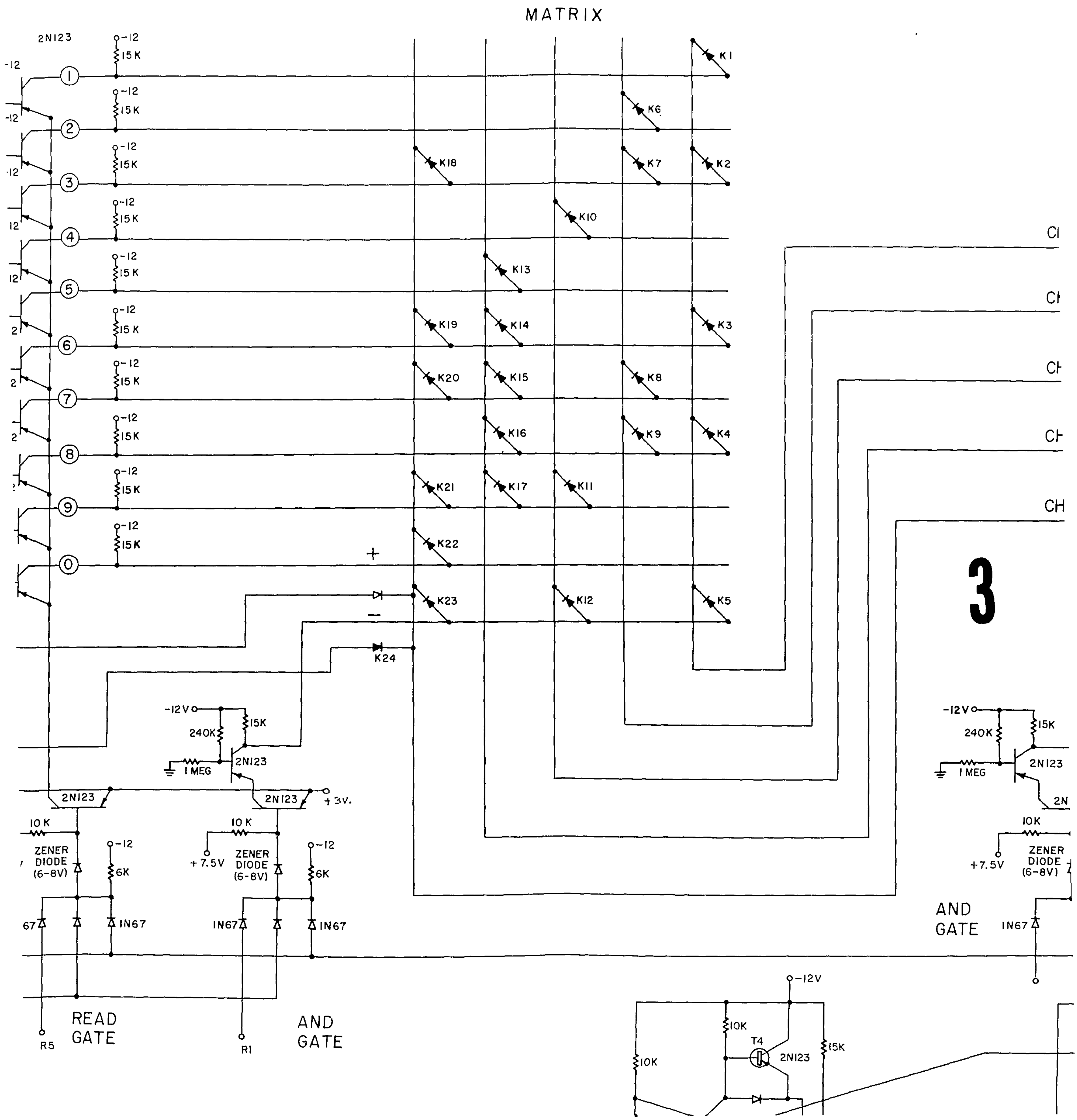
BIQUINARY ANALOG TO DIGITAL CONVERTER

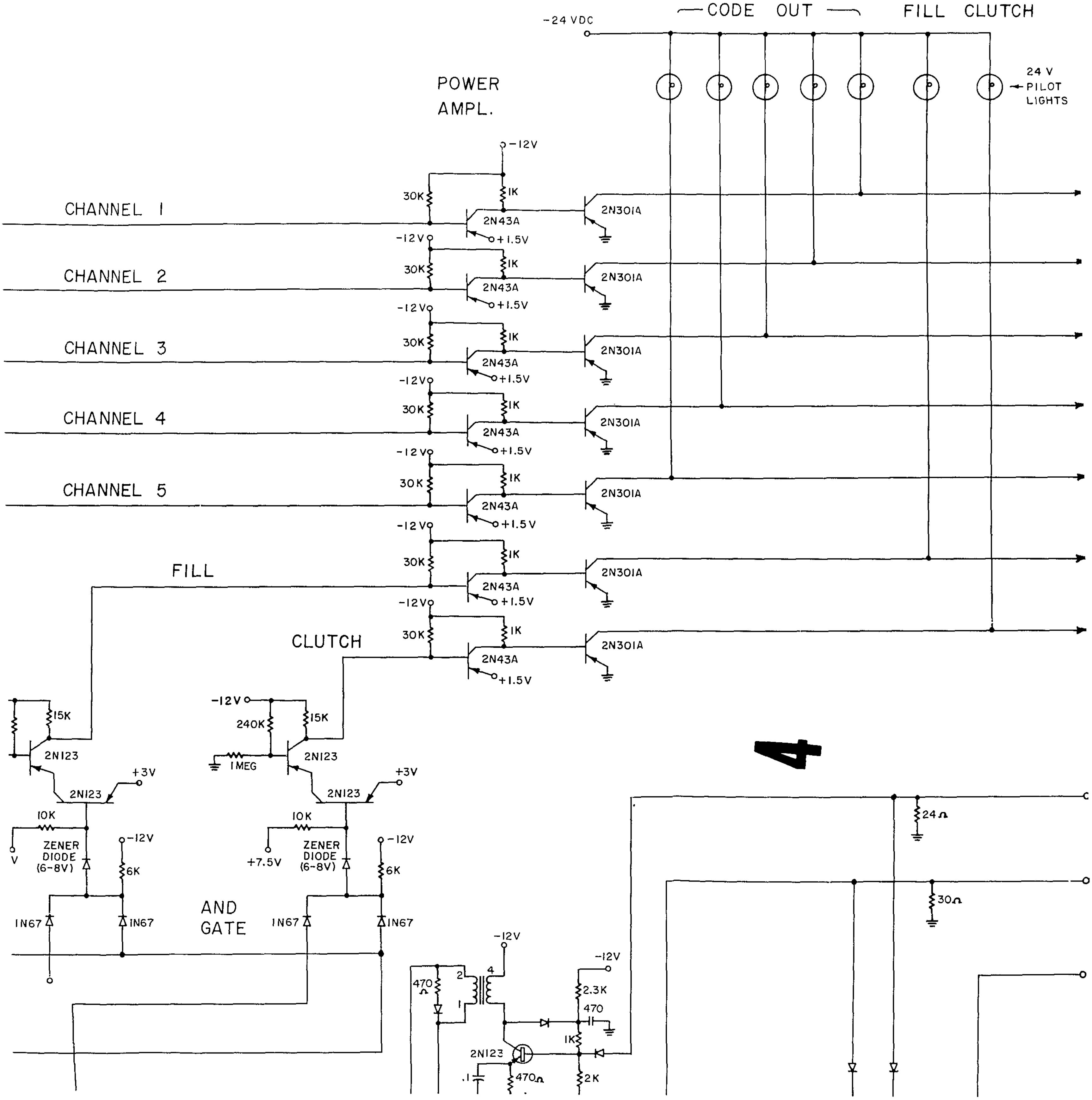


DIGITAL CLOCK

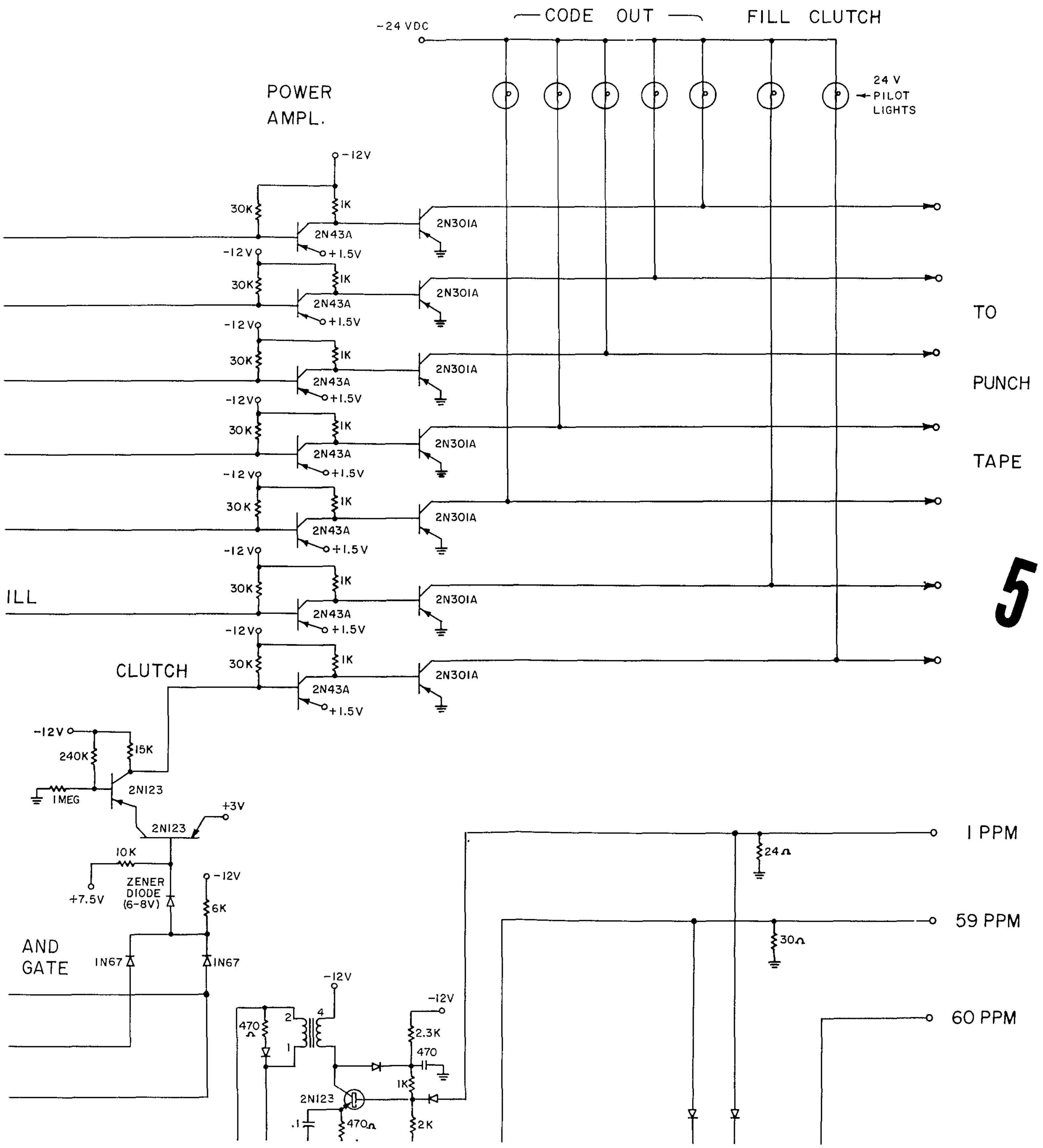
10 WIRE CODES




MATRIX
2N123
-12
15K
K1
K2
K3
K4
K5
K6
K7
K8
K9
K10
K11
K12
K13
K14
K15
K16
K17
K18
K19
K20
K21
K22
K23
K24
+
−
-12V
240K
15K
1 MEG
2N123
+3V.
10K
ZENER DIODE (6-8V)
6K
IN67
+7.5V
READ GATE
AND GATE
R5
R1
3
-12V
10K
T4
15K

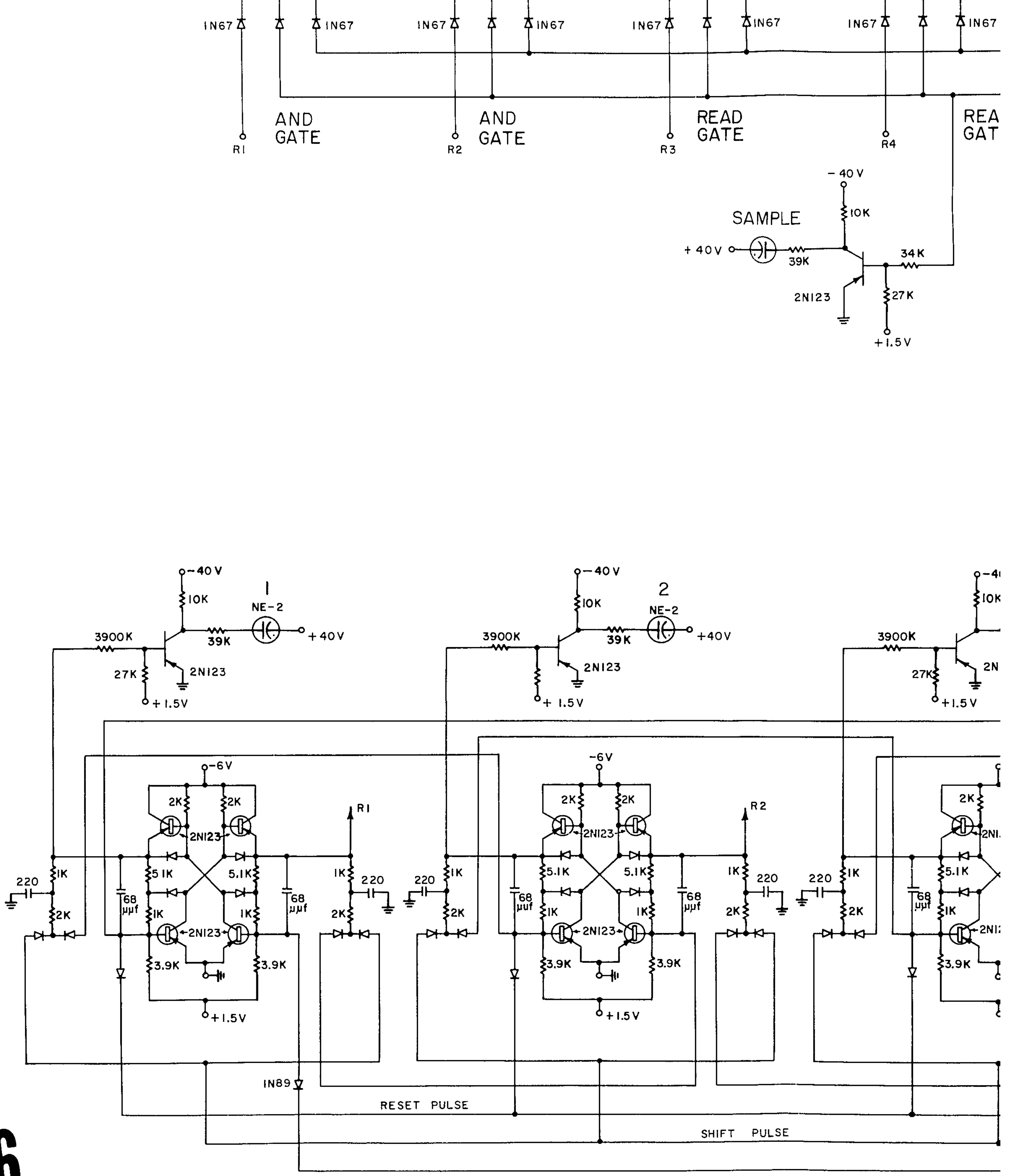


CODE OUT
FILL CLUTCH
-24 VDC
24 V PILOT LIGHTS
POWER AMPL.
-12V
30K
1K
2N43A
+1.5V
2N301A
CHANNEL 1
CHANNEL 2
CHANNEL 3
CHANNEL 4
CHANNEL 5
FILL
CLUTCH
15K
240K
1MEG
2N123
+3V
10K
ZENER DIODE (6-8V)
+7.5V
6K
IN67
AND GATE
470 Ω
2.3K
470
2K
.1
470Ω
24Ω
30Ω

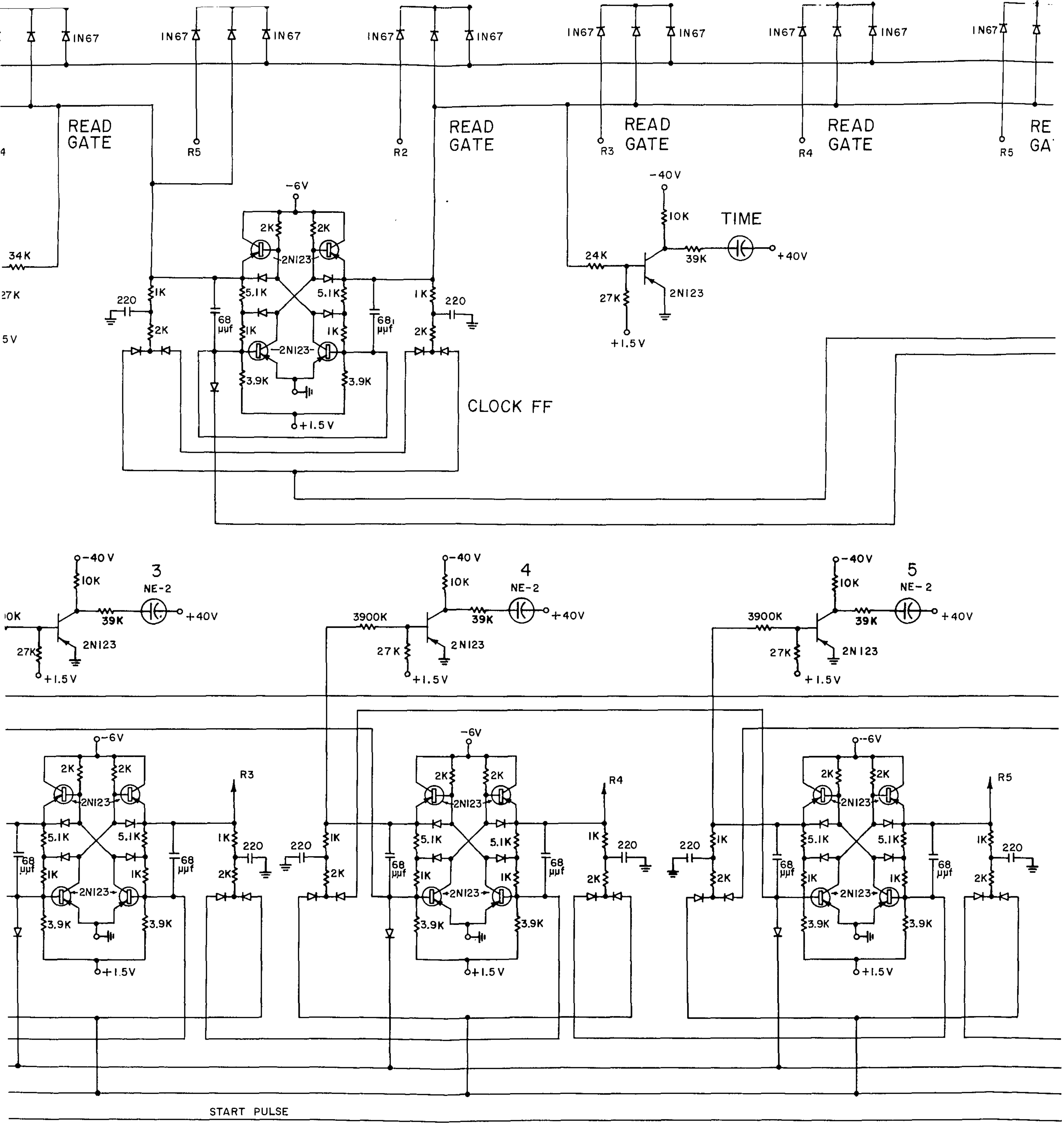


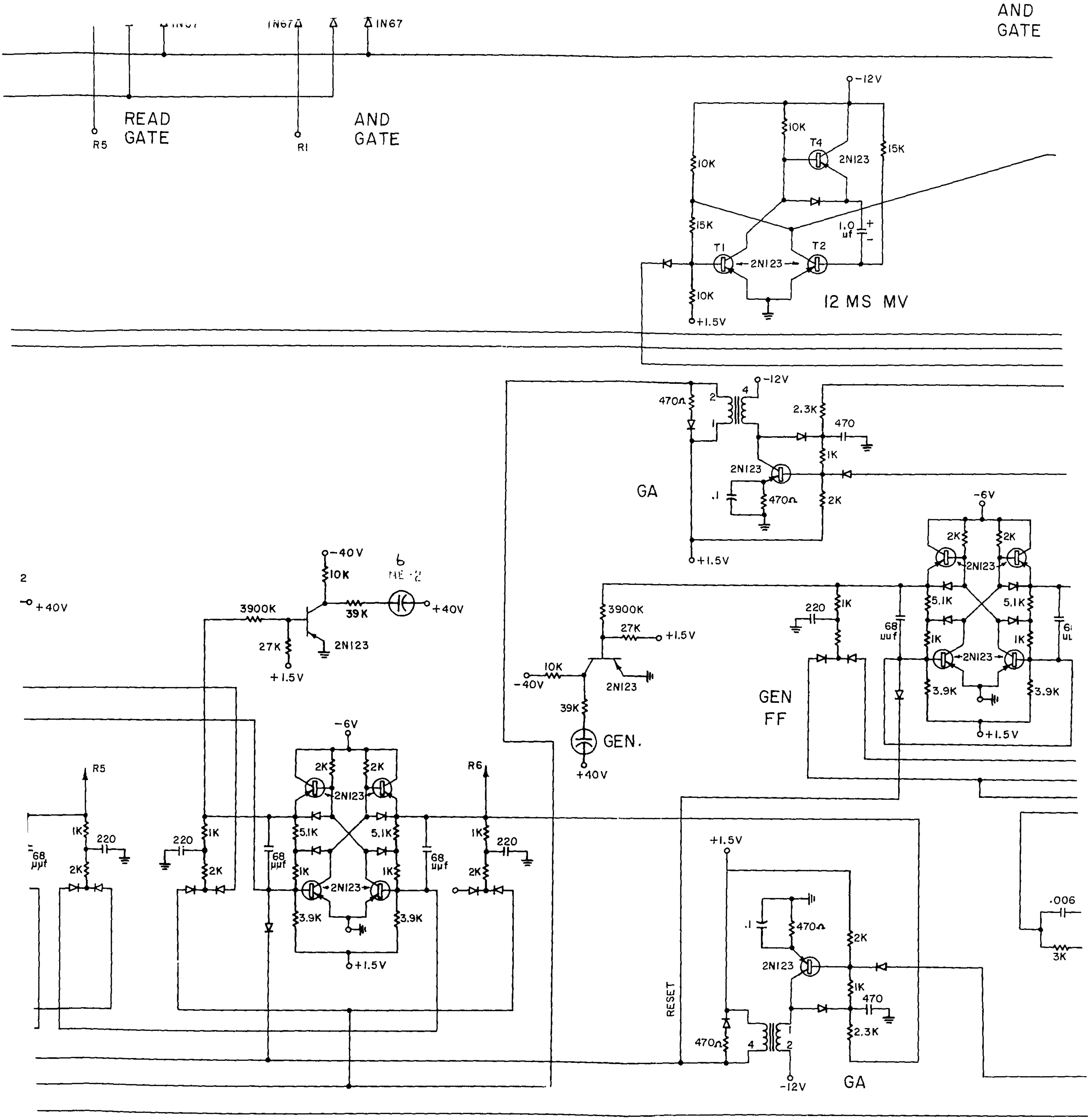
CODE OUT
FILL CLUTCH
-24 VDC
24 V PILOT LIGHTS
POWER AMPL.
-12V
30K
1K
2N43A
+1.5V
2N301A
TO PUNCH TAPE
ILL
CLUTCH
240K
15K
1MEG
2N123
+3V
10K
+7.5V
ZENER DIODE (6-8V)
6K
AND GATE
1N67
470
2.3K
1K
2K
.1
470Ω
1 PPM
24Ω
59 PPM
30Ω
60 PPM

5

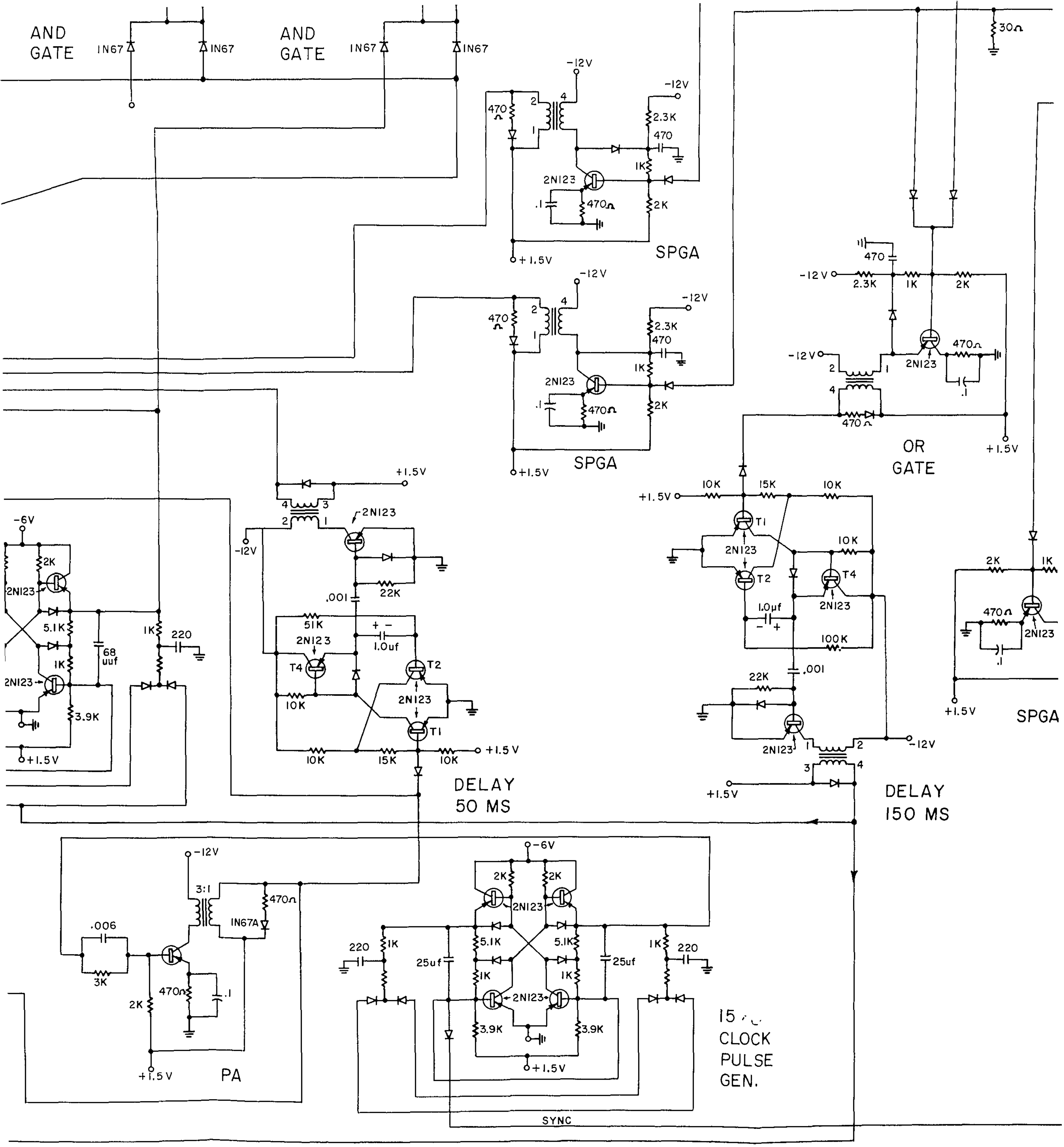

IN67
AND
GATE
READ
GATE
REA
GAT
R1
R2
R3
R4
-40V
10K
SAMPLE
+40V
39K
34K
2N123
27K
+1.5V
1
2
NE-2
3900K
27K
2K
2N123
5.1K
1K
3.9K
-6V
220
68 µµf
IN89
RESET PULSE
SHIFT PULSE

6


READ GATE
CLOCK FF
TIME
IN67
R2
R3
R4
R5
-6V
-40V
+40V
+1.5V
2N123
NE-2
3
4
5
3900K
10K
39K
27K
24K
34K
2K
1K
5.1K
3.9K
220
68 μμf
START PULSE


AND GATE
IN67
IN67
READ GATE
R5
R1
AND GATE
-12V
10K
T4
2N123
15K
10K
15K
1.0 uf
T1
T2
2N123
10K
+1.5V
12 MS MV
470Ω
-12V
2.3K
470
1K
2N123
GA
.1
470Ω
2K
+1.5V
-6V
2K
2K
2N123
-40V
10K
6
NE-2
+40V
39K
3900K
27K
2N123
+1.5V
2
+40V
3900K
27K
+1.5V
10K
-40V
2N123
39K
GEN.
+40V
220
1K
68 uuf
5.1K
5.1K
1K
1K
2N123
3.9K
3.9K
+1.5V
GEN FF
-6V
2K
2K
2N123
5.1K
5.1K
1K
1K
2N123
3.9K
3.9K
+1.5V
R5
R6
1K
220
2K
68 µµf
220
1K
2K
68 µµf
68 µµf
1K
220
2K
+1.5V
.1
470Ω
2K
2N123
1K
470
2.3K
RESET
470Ω
4
1
2
-12V
GA
.006
3K

8



9

Figure A.
Analo

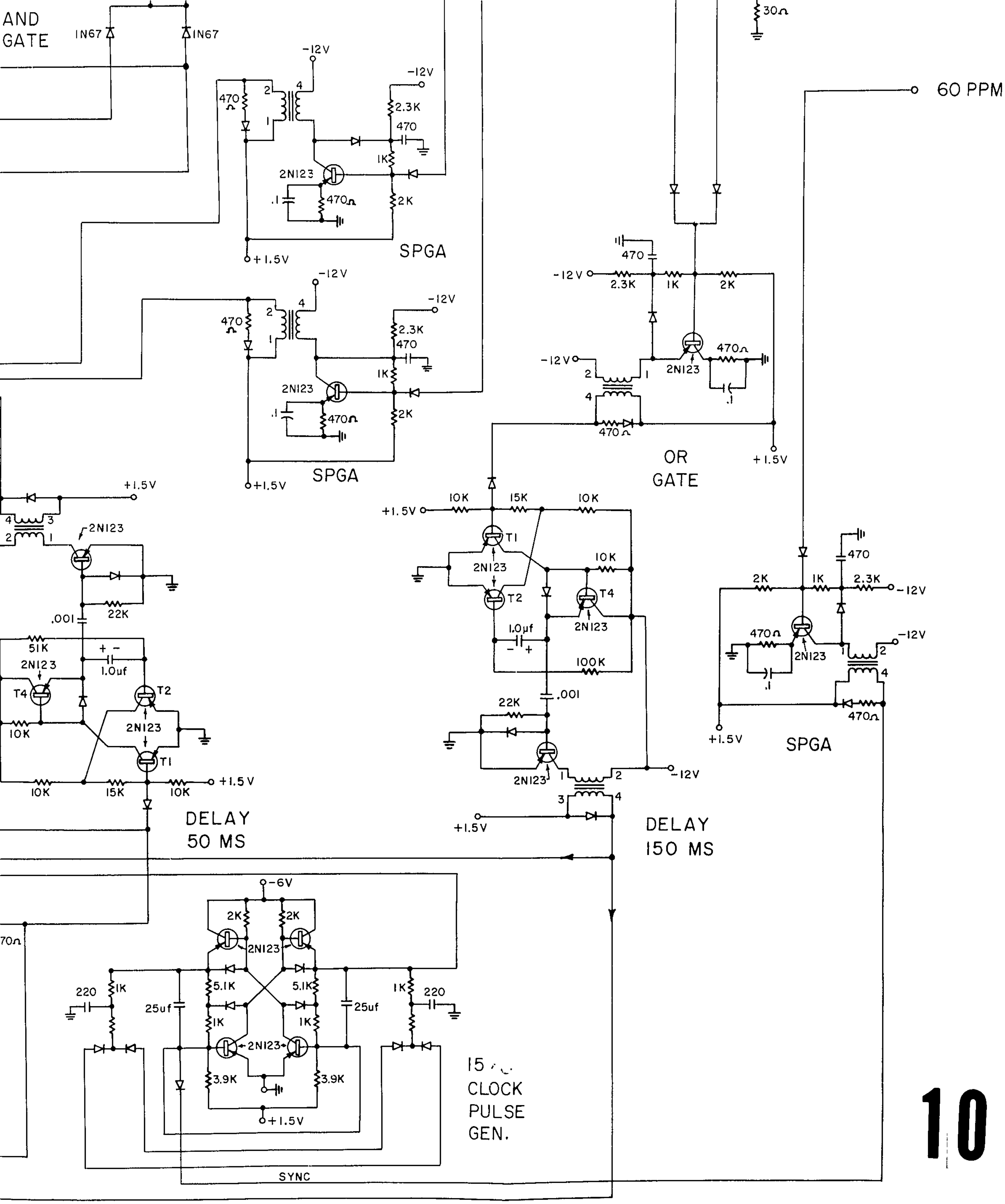


Figure A. 7. Schematic of Biquinary Analog to Digital Converter

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AF Cambridge Research Laboratories, Bedford, Mass. Electronics Research Directorate
ANALOG-TO-DIGITAL DATA REDUCTION SYSTEM, by Joseph E. Reegan. January 1962. 27 pp incl. illus. AFCRL-62-16

Unclassified report

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2. Data processing systems
I. Reegan, Joseph E.

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minute intervals and feeds these mean values through an X - Y variplotter associated with the computer where a distribution curve is automatically plotted. This data reduction system, although of special value in radio propagation research, may also be used wherever amplitude is plotted vs. time.

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